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Hospital Incinerator Operator Training Course
Volume 1, Student Handbook

Midwest Research Inst., Cary, NC

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Student Handbook

control technology center

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Neulicht, R. M.; Chaput, L. S.; Wallace, D. D.;
Turner, M. B.; Smith, S. G.

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James Eddinger, Office of Air Quality Planning and Standards
Justice Manning, Center for Environmental Research

16. ABSTRACT

This document is Volume I of a three-volume training course for operators of hospital waste incinerators. Volume II is the Presentation Slides (EPA 450/3-89-004). Volume III is the Instructor Handbook (EPA 450/3-89-010). This training course was originally prepared by the Control Technology Center for the State of Maryland. The purpose of this course is to provide hospital waste incinerator operators with a basic understanding of the principles of incineration and air pollution control and to identify, generally, good operation and maintenance (O&M) practices. Proper O&M, in addition to reducing air emissions, improves equipment reliability and performance, prolongs equipment life, and helps to ensure proper ash burnout. The course is not intended to replace site-specific, hands-on training of operators with the specific equipment to be operated.

Volume I is narrative in style and can be used as a reference at the completion of the class. Review questions and answers for students are provided at the end of each classroom session. The course includes 11 separate classroom sessions covering topics such as basic combustion principles and incinerator design; air pollution control equipment design, function, operation, and monitoring; incinerator operation; maintenance inspections; typical problems; and State regulations. Volume II contains classroom materials including a copy of the presentation slides so that students can follow along during the class and worksheets that can be completed during the classroom sessions.

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VOLUME I

STUDENT HANDBOOK

CONTROL TECHNOLOGY CENTER

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VOLUME I
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Prepared by:

Midwest Research Institute
Suite 350
401 Harrison Oaks Boulevard
Cary, North Carolina 27513

Prepared for:

James A. Eddinger
Office of Air Quality Planning and Standards
U. S. Environmental Protection Agency
Research Triangle Park, North Carolina 27711

Control Technology Center
U. S. Environmental Protection Agency
Research Triangle Park, North Carolina 27711

NOTICE

This training course is intended to provide the operator with a basic understanding of the principles of incineration and air pollution control. This training course is not a substitute for site-specific hands-on training of the operator with the specific equipment to be operated.

DISCLAIMER

This document generally describes the proper operation of a hospital waste incinerator. It is based on EPA's review and assessment of various scientific and technical sources. The EPA does not represent that this document comprehensively sets forth procedures for incinerator operation, or that it describes applicable legal requirements, which vary according to an incinerator's location. Proper operation of an incinerator is the responsibility of the owner and operator.

Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

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PREFACE

The program for development of a training course for operators of hospital medical waste incinerators was funded as a project of EPA's Control Technology Center (CTC).

The CTC was established by EPA's Office of Research and Development (ORD) and Office of Air Quality Planning and Standards (OAQPS) to provide technical assistance to State and local air pollution control agencies. Three levels of assistance can be accessed through the CTC. First, a CTC HOTLINE has been established to provide telephone assistance on matters relating to air pollution control technology. Second, more in-depth engineering assistance can be provided when appropriate. Third, the CTC can provide technical guidance through publication of technical guidance documents, development of personal computer software, and presentation of workshops on control technology matters. The technical guidance projects, such as this one to develop training materials for hospital waste incinerator operators, focus on topics of national or regional interest that are identified through contact with State and local agencies.

The CTC became interested in developing a basic training course for operators of hospital waste incinerators with the idea that properly trained operators can improve operating and maintenance procedures and, consequently, minimize air emissions. This training course was prepared to provide the operator with a basic understanding of the principles of incineration and air pollution control and to identify, in a general sense, good operating practices. The course is not intended as a substitute for site-specific hands-on training of the operator with the specific equipment to be operated.

The course consists of three volumes:

Volume I--Student Handbook
Volume II Course--Presentation Slides
Volume III--Instructor Handbook

This volume is a student handbook which includes 11 separate sessions. The handbook sessions cover, in more detail, the same topics your instructor will cover during the course. The handbook also includes a glossary of terms and a list of suggested documents from which further information can be obtained. The student handbook is narrative in style and is for your use not only during the course but also afterwards as a valuable reference when you go back to work.

TABLE OF CONTENTS

Page

INTRODUCTION.. 1

SESSION 1. PROTECTING THE ENVIRONMENT - YOUR RESPONSIBILITY..... 1-1

SESSION 2. BASIC COMBUSTION PRINCIPLES......................... 2-1

SESSION 3. BASIC INCINERATOR DESIGN............................ 3-1

SESSION 4. AIR POLLUTION CONTROL EQUIPMENT DESIGN AND FUNCTIONS 4-1

SESSION 5. MONITORING AND AUTOMATIC CONTROL SYSTEMS............. 5-1

SESSION 6. INCINERATOR OPERATION............................... 6-1

SESSION 7. AIR POLLUTION CONTROL SYSTEMS OPERATION.............. 7-1

SESSION 8. MAINTENANCE INSPECTION--A NECESSARY PART OF YOUR JOB 8-1

SESSION 9. TYPICAL PROBLEMS.................................... 9-1

SESSION 10. STATE REGULATIONS.................................. 10-1

SESSION 11. SAFETY: AN IMPORTANT PART OF YOUR JOB............... 11-1

GLOSSARY

SUGGESTED FURTHER READING

SESSION 1.
PROTECTING THE ENVIRONMENT - YOUR RESPONSIBILITY

SESSION 1. PROTECTING THE ENVIRONMENT - YOUR RESPONSIBILITY

TABLE OF CONTENTS

Page

SESSION GOAL AND OBJECTIVES.. 1-1

WHY INCINERATION... 1-1

ENVIRONMENTAL CONCERNS... 1-2
  Pathogen Destruction... 1-2
  Air Pollutants of Concern.. 1-2
  Solid Waste Ash Quality.. 1-4

THE OPERATOR - YOUR ROLE... 1-5

REFERENCES FOR SESSION 1... 1-7

LIST OF FIGURE

Page

Figure 1-1. Schematic of incinerator showing sources of pollutants of concern.............................. 1-3

INTRODUCTION

DESCRIPTION

This course is designed for hospital waste incinerator operators. It focuses on the basic principles of combustion; the proper design, operation, and maintenance of hospital waste incineration systems and their associated air pollution control systems; and the operator's role in reducing air pollution and complying with applicable regulations.

COURSE GOALS AND OBJECTIVES

COURSE GOALS

1. To provide you with the knowledge of the basic principles of incineration and proper operation and maintenance practices for hospital waste incinerators and air pollution control systems.
2. To help you understand your role in protecting the environment by reducing air pollution and disposing of ash properly.
3. To increase your awareness of regulatory requirements and safety concerns.

COURSE OBJECTIVES

At the conclusion of this course you will:

1. Understand the air pollution problems associated with hospital waste incinerators and how to minimize them.
2. Be aware of common operational problems and safety hazards and their causes.

3. Know how to use monitoring and recordkeeping to improve operation and maintenance and to aid in compliance with regulatory requirements.

US [illegible] THE HANDBOOK

The material in the har [illegible] covers the same topics your instructor will cover. Your handbook [illegible] your use not only during the course but also afterwords as a valuable reference when you go back to work.

There are one or more review exercises in each session. To complete an exercise, place a piece of paper across the page, covering the questions below the one you are answering. After writing your answer on a separate piece of paper (not in the book), slide the paper down to uncover the next question. The answer for the first question will be given on the right side of the page, separated by a line from the second question, as shown on the next page. All answers to review questions will appear below and to the right of their respective questions. The answer will be numbered to match the question. Complete each review exercise in the book. If you are unsure about a question or answer, review the material in the session.

A list of references used during preparation of the course is provided at the end of each session. A list of documents which may be particularly helpful to students wishing to learn more about particular topics is presented at the end of the handbook.

SESSION 1.
PROTECTING THE ENVIRONMENT - YOUR RESPONSIBILITY

SESSION GOAL AND OBJECTIVES

GOAL

To familiarize you with
- Why hospital waste is incinerated;
- What the environmental concerns are related to incineration; and
- What air pollutants are important.

OBJECTIVES

Upon completing this session, you should be able to:

1. Name the primary reasons that hospital wastes are incinerated;
2. Identify environmental concerns related to incineration;
3. List the types of air pollutants of concern that could be emitted to the atmosphere from hospital waste incinerators; and
4. Recognize your role in preventing air pollution and improper ash disposal.

WHY INCINERATION

Hospitals generate large quantities of waste. Some of the types of wastes that are generated are infectious wastes, spent alcohols or other solvent materials, plastic containers, and general rubbish. Historically, much of this waste has been disposed of in landfills. However, as many landfills reach capacity and people become more concerned with environmental problems caused by improper disposal of waste materials, incineration has become an attractive option for handling wastes. Incineration does not eliminate the need to landfill waste, but it does reduce the amount of waste that must be placed in landfills. It also generates a waste for landfills that is more acceptable than recognizable hospital wastes to the general public.

The primary advantages of incineration are:

- It greatly reduces the weight and volume of waste material that must be disposed of in landfills.
- It destroys organic materials that may be harmful or that may be degradable to harmful materials in landfills.
- The incinerator sterilizes the waste. That is, the high temperatures in incinerators can destroy any pathogens that may be in infectious waste materials.
- The incinerator destroys animal or human pathological wastes or other hospital waste materials that the general public finds objectionable to handle or see.

ENVIRONMENTAL CONCERNS

The general public will not accept incineration as an option for treating hospital wastes if they do not believe that it is safe environmentally. The primary concerns are that the pathogens are destroyed in the incinerator, that the ash residue is of acceptable quality, and that harmful air pollutants are not emitted from the incinerator. This section will present some of the terminology that is important to understanding these concerns. The remainder of the course will describe how an incineration system can be operated and maintained in a way that keeps environmental releases at an acceptable level.

PATHOGEN DESTRUCTION

The primary objective of hospital waste incineration is the destruction of pathogens in infectious wastes. Pathogens are those biological components of the waste that can cause an infectious disease.

The pathogens in infectious waste can be destroyed by the high temperatures achieved in hospital waste incinerators. Almost no information is available on the incinerator conditions required to destroy all pathogens, but temperature and time of exposure are known to be important. Emissions of pathogens from the incinerator could be attributed to insufficient retention time and temperature as a result of the following conditions:

1. Initial charging of the incinerator before operating temperatures are achieved;
2. Failure to preheat the refractory lining;
3. Temperature fluctuations caused by intermittent use;
4. Exceeding design airflow rates, thereby reducing the retention time;
5. Charging beyond incinerator capacity; and
6. Excessive moisture content of the waste.

Other factors such as the type of refractory lining, the positioning and number of burners, and the precision of temperature controlling devices also can affect pathogen destruction. The destruction of pathogens in the incinerator ash also depends on temperature and time of exposure.

AIR POLLUTANTS OF CONCERN

Figure 1-1 shows an incinerator and the main pollutants of concern. These pollutants are:

- Particulate matter;
- Hydrochloric acid gas;
- Toxic metals;
- Organic compounds; and
- Carbon monoxide.

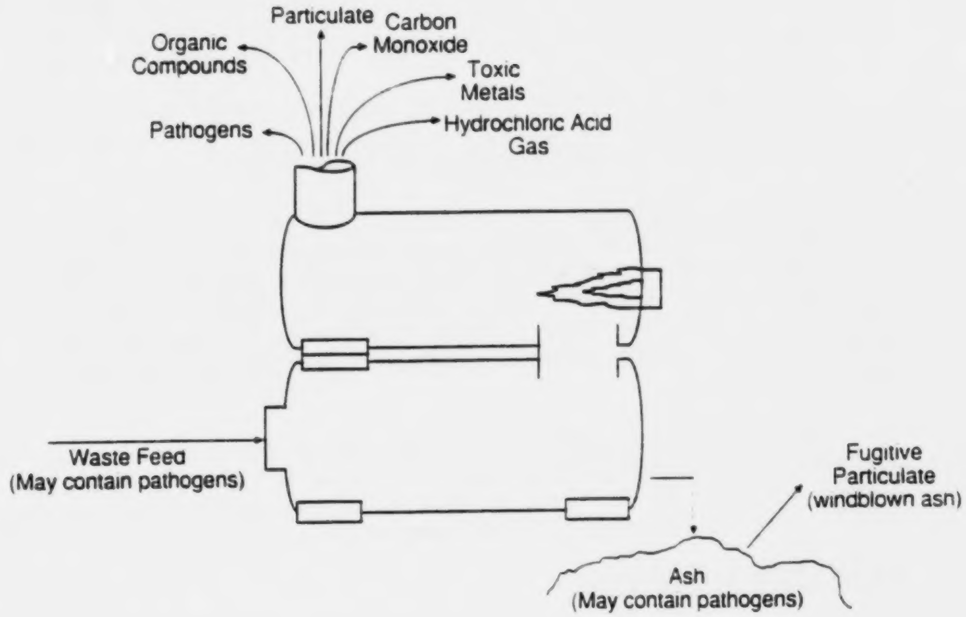

Particulate
Carbon Monoxide
Organic Compounds
Toxic Metals
Pathogens
Hydrochloric Acid Gas
Waste Feed (May contain pathogens)
Fugitive Particulate (windblown ash)
Ash (May contain pathogens)

Figure 1-1. Schematic of incinerator showing sources of pollutants of concern.

Particulate matter may be defined as fine liquid or solid matter such as dust, smoke, mist, or fumes found in the gaseous emissions from the incinerator. Particulate matter emissions may have a dark or light color. Particulate matter emissions can be described in terms of opacity. Opacity is the degree to which light is obscured by a polluted gas--a clear window has 0 percent opacity while black paper has 100 percent opacity. Opacity may be measured with the naked eye or using a transmissometer (opacity monitor). Particulate matter is a problem because it can cause or aggravate respiratory problems in humans. It also creates aesthetic problems since it is readily noticed and is a nuisance because of soiling of exposed surfaces on houses and cars.

Hydrochloric (HCl) acid is generated when polyvinyl chloride (PVC) plastic (usually clear plastic) material is burned in the incinerator. The appearance of a white plume or cloud a short distance above the stack indicates that HCl is condensing. The major concerns about HCl are that it causes respiratory problems in humans, contributes to acid rain problems, and causes material damage to metals and concrete.

Toxic metals include cadmium, arsenic, beryllium, chromium, nickel, lead, and mercury. These metals may be found in hospital wastes. These metals are known to be hazardous to human health.

Organic compounds are compounds that contain primarily carbon and hydrogen and may also contain other elements such as oxygen, nitrogen, and chlorine in smaller amounts. Some organic compounds are known to cause or are suspected of causing cancer and are considered hazardous air pollutants. The public's primary concern is related to dioxin and furan emissions, but other organic compounds such as benzene and vinyl chloride may be emitted.

Carbon Monoxide (CO) also is generated during combustion if the combustor is not operated properly. (Your automobile generates some amount of CO.) CO is toxic to humans if concentrations are high enough, and it also is an indicator of combustion quality.

SOLID WASTE ASH QUALITY

One of the major objectives of incineration is to generate a high quality ash for land disposal. All pathogens should be destroyed, and almost all organic material should be completely burned. Ideally, no large chunks of unburned waste material (other than metals or glass) should remain in the waste. Attempting to dispose of hospital waste that is incompletely burned may result in monetary fines, or the landfill may refuse to accept the waste. From an aesthetic standpoint, large pieces of medical waste that have not been burned may be of concern to the public. A measure of ash quality is "burnout," which is the percentage of organic material remaining in the waste. For example, a burnout of 95 percent means that the ash can contain only 5 percent organics.

Adequately burned and quenched ash may be disposed of in a sanitary (municipal) landfill. The ash should be stored in covered containers or

SESSION 2. BASIC COMBUSTION PRINCIPLES

TABLE OF CONTENTS

Page

SESSION GOAL AND OBJECTIVES.................................... 2-1
THE COMBUSTION REACTION....................................... 2-1
OPERATING FACTORS RELATED TO COMBUSTION........................ 2-3
PRODUCTS OF THE COMBUSTION REACTION............................ 2-7
COMBUSTION INDICATORS... 2-7
REFERENCES FOR SESSION 2....................................... 2-10

LIST OF FIGURE

Page

Figure 2-1. Relationship of temperature to excess air............ 2-5

LIST OF TABLE

Page

TABLE 2-1. CHARACTERIZATION OF HOSPITAL WASTE.................... 2-6

SESSION 2.
BASIC COMBUSTION PRINCIPLES

kept wet prior to transport to the landfill to prevent fugitive emissions. Individual landfills may have requirements that must be followed in order for your waste to be accepted. You should familiarize yourself with these requirements to prevent refusal of the waste.

THE OPERATOR - YOUR ROLE

It is the operator's role and responsibility to protect the environment by:

1. Complying with all emission limits and operating practices specified in the permit to operate.
2. Minimizing emissions of particulate matter, HCl, toxic metals, carbon monoxide, and organic compounds through proper incinerator and air pollution control device operation;
3. Operating the incinerator to generate high quality ash that is sterile and can be disposed of in landfills;
4. Minimizing particulate matter emissions from ash handling;
5. Disposing of ash properly by sending it to appropriate disposal sites; and
6. Performing the regular maintenance inspections (described in Session 8) to catch any operational problems early.

The rest of this document will provide you with information to help you meet this responsibility.

REVIEW EXERCISE

1. List three advantages of hospital waste incineration	
2. List the main pollutants of concern.	1. Reduces volume and weight of waste Destroys pathogens (sterilizes waste) Destroys organics Destroys objectional waste materials
3. Emissions of hydrochloric acid gas occur because of the presence of ________ in the feed material.	2. Particulate matter Hydrochloric acid gas Toxic metals Hazardous organics Carbon monoxide
4. Waste ash that does not meet landfill requirements can be refused by the landfill, and monetary fines may be imposed for improper ash disposal. True or false.	3. Polyvinyl chloride plastic
5. To minimize environmental problems, you should properly: a) ____________ and b) ____________	4. True
6. You should perform regular ________ inspections to catch any problems early.	5. a) operate your incinerator b) handle and dispose of the ash.
	6. Maintenance

REFERENCES FOR SESSION 1

1. U. S. Environmental Protection Agency. EPA Guide for Infectious Waste Management. EPA/530-SW-86-014. (NTIS PB 86-199130). U. S. EPA Office of Solid Waste. May 1986.

2. Ontario Ministry of the Environment. Incinerator Design and Operating Criteria, Volume II-Biomedical Waste Incineration. October 1986.

3. Barbeito, M. S. and M. Shapiro. Microbiological Safety Evaluation of a Solid and Liquid Pathological Incinerator. Journal of Medical Primatology. pp. 264-273. 1977.

4. U. S. Environmental Protection Agency. Hospital Waste Combustion Study: Data Gathering Phase. EPA 450/3-88-017. December 1988.

SESSION 2.
BASIC COMBUSTION PRINCIPLES

GOAL AND OBJECTIVES

GOAL

To familiarize you with:

- Basic combustion terminology that will be used in the remainder of the course;
- How the combustion process works and how you affect the process;
- Indicators of good combustion and poor combustion; and
- How the combustion process affects air emissions.

OBJECTIVES

Upon completing this session, you should be able to:

1. List the three factors that are needed for combustion to occur;
2. List the combustion products generated under good combustion and poor combustion conditions;
3. Describe the relationship among fuel, air, and waste control;
4. Describe how combustion air requirements are affected by waste characteristics;
5. Describe what happens when you have too much or too little combustion air;
6. Estimate the heating value of different waste types;
7. Describe how the combustion gas oxygen level is related to combustion air;
8. Define opacity and describe what happens to opacity under poor combustion conditions; and
9. Recognize the definitions of these terms:
    - Heating value;
    - Stoichiometric (theoretical) air;
    - Excess air;
    - Starved air; and
    - Products of incomplete combustion.

THE COMBUSTION REACTION

Combustion of hospital wastes is a chemical reaction. In the incinerator, organic materials and oxygen react rapidly and violently to produce combustion gases and energy in the form of heat and light. The reaction works like this:

$$\text{Organic Material + Oxygen} \xrightarrow[\text{Heat}]{} \text{Combustion Gas + Solid Residue + Energy(Heat)}$$

For the reaction to begin and to keep going, all three elements--organic material, oxygen, and heat--must be present.

The organic material used in the reaction comes from two sources, waste and auxiliary fuel. Some organic material is contained in most hospital waste. Depending on the fraction of organics and the specific organic composition, the waste may be adequate to sustain combustion. The other source of organic material is auxiliary fuel. Auxiliary fuel is always used to preheat the incinerator and to start combustion; auxiliary fuel may be used to maintain combustion if the waste material does not contain enough organic material to maintain high temperatures.

The oxygen needed for the combustion reaction is supplied by the ambient combustion air. Combustion air is supplied to the combustion chambers through air ports by a forced draft fan, by an induced draft fan, or by natural draft. In general, this air contains about 21 percent oxygen (O_2) and 79 percent nitrogen (N_2), so about 21 percent of the total combustion air fed to the incinerator is oxygen that is available to react with the organic material in the waste and fuel.

The combustion reaction between the organic material and oxygen that causes the organics to burn will occur only after the temperature of the organic material is raised to the point that combustion can begin. Each specific organic compound has its own temperature at which the reaction occurs, but temperatures in the range of 1000° to 1800°F generally are considered to provide "good combustion conditions." Energy in the form of heat is required to raise the temperatures of the incinerator chamber and organic material and O_2. Initially, this energy usually is supplied by the pilot and auxiliary fuel burners. After the system is in full operation, the energy released from the burning waste often is adequate to maintain these high temperatures.

Hospital wastes contain two types of organic materials--volatile matter and fixed carbon. These two types of materials are involved in distinct types of combustion reactions, and the operating variables that control the two types of reaction are different.

Volatile matter is that portion of the waste that is vaporized (or evaporated) when the waste is heated. Combustion occurs after the material becomes a gas. The combustion variables that influence this reaction are gas temperature, residence time, and mixing. A minimum temperature is needed to start and sustain the chemical reaction. Residence time is the length of time, generally measured in seconds, that the combustion gas spends in the high temperature combustion chamber. The residence time must be long enough for the reaction to be completed before it leaves the high temperature zone. Turbulent mixing of the volatile matter and combustion air is required to ensure that the organic material and oxygen are well mixed.

Fixed carbon is the nonvolatile organic portion of the waste. For fixed carbon, the combustion reaction is a solid-phase reaction that occurs primarily in the waste bed (although some materials may burn in suspension). Key operating parameters are bed temperature, solids retention time, and mechanical turbulence in the bed. The solids retention time is the length of time that the waste bed remains in the primary chamber. Mechanical turbulence of the bed is needed to expose all the solid waste to oxygen for complete burnout. Without mechanical turbulence, the ash formed during combustion can cover the unburned waste and prevent the oxygen necessary for combustion from contacting the waste.

OPERATING FACTORS RELATED TO COMBUSTION

The three operating factors that have the greatest effects on the combustion reaction are combustion air flow rate and distribution, operating temperatures, and waste feed rate and characteristics. These three factors are all related, and the combustion reaction is controlled by controlling them.

The two key questions about combustion air that we will address are:

- How much combustion air is needed to sustain the combustion reaction?
- What happens if there is too much or too little combustion air?

COMBUSTION AIR

In the chemical reaction between organic materials and oxygen, the amount of oxygen required under ideal or "perfect" conditions to burn all of the organic materials with no oxygen left over is called the stoichiometric (or theoretical) oxygen level. The amount of combustion air associated with that oxygen level is called the stoichiometric air level. Air flows greater than those required at stoichiometric levels are called excess air levels, and airflows less than those required at stoichiometric levels are called deficient air or substoichiometric starved air levels. Typically a hospital incinerator operates with an overall 140 to 200 percent excess air level. That is, the incinerator operates with about one and one-half to two times more air than required at stoichiometric levels. Excess air is used to assure that enough oxygen is available for complete combustion.

Computation of exact stoichiometric air requirements for a waste incinerator is difficult because it depends on the chemical composition of the waste and fuel. However, stoichiometric air requirements can be estimated on the basis of the energy input (or heat input) to the incinerator. Heat input is a measure of the energy released when the waste and fuel are burned. It is measured in British thermal units (Btu's). Generally about 1 standard cubic foot of combustion air is required per 100 Btu's of heat input to the incinerator.

Maximum combustion temperatures are always attained at stoichiometric conditions. As the amount of excess air is increased above the stoichiometric point, the temperature in the incinerator drops because energy is used to heat the combustion air. If the amount of combustion air is too great, the temperature can drop below "good combustion temperature," and undesirable combustion products are generated as a result of incomplete combustion. As the amount of excess air is decreased, the combustion temperature increases until it becomes maximum at the stoichiometric point. Below the stoichiometric point, the temperature decreases because complete combustion has not occurred. A graphical representation of the relationship between combustion temperature and excess air level is shown in Figure 2-1. At air levels below the stoichiometric point, some of the organics are not reacted, and pollutants are emitted as a result of incomplete combustion..

If an incinerator operates with excess air, some of the oxygen in the combustion air does not react. Increases in excess air levels result in increases in combustion gas oxygen levels. The oxygen concentration of the effluent gas stream is a useful indicator of the combustion excess air levels and is useful for monitoring the combustion process.

COMBUSTION TEMPERATURE

Temperature also plays an important role in the combustion of hospital wastes. Temperatures should be maintained at levels above design temperatures to ensure pathogen destruction and to sustain the combustion reaction. However, temperatures that are too high also cause problems. Continuous exposure of the combustor refractory to high temperatures is generally not desirable because it can cause the ash to fuse and can cause thermal damage to the refractory. The lower and upper limits for "proper" temperature ranges are discussed in later sessions of this course.

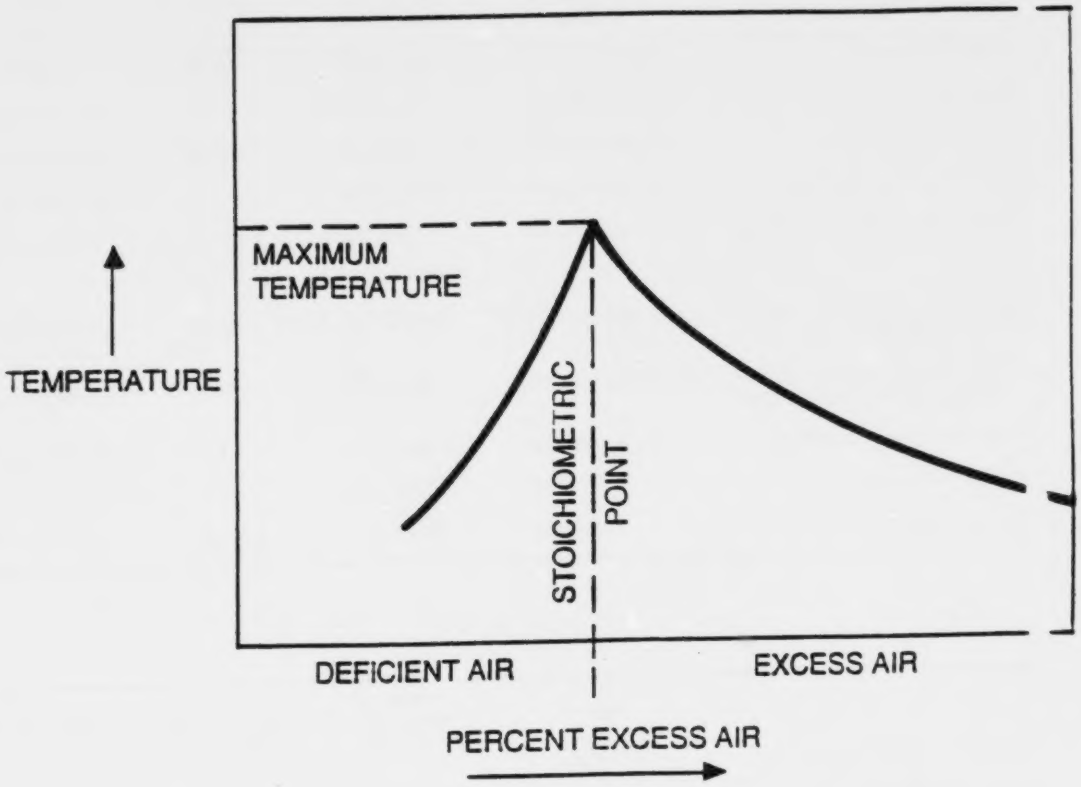
WASTE CHARACTERISTICS

The primary characteristics of the waste that affect the combustion reaction are the heating value, the moisture content, and the chlorine content. Typical heating values and moisture contents of some waste materials typically fired to hospital waste incinerators are shown in Table 2-1.

The heating value of a waste is a measure of the energy released when the waste is burned. It is measured in units of Btu/lb (J/kg). A heating value of about 5,000 Btu/lb (11.6×10^6 J/kg) or greater is needed to sustain combustion. Wastes with lower heating values can be burned, but they will not maintain adequate temperature without the addition of auxiliary fuel. The heating value of the waste also is needed to calculate total heat input to the incinerator where:

Heat Input (Btu/h) = Feed Rate (lb/h) x Heating Value (Btu/lb)

Moisture is evaporated from the waste as the temperature of the waste is raised in the combustion chamber; it passes through the incinerator, unchanged, as water vapor. This evaporation of moisture uses energy and reduces the temperature in the combustion chamber. The water vapor also increases the combustion gas flow rate, which reduces combustion gas residence time.



CONTROL OF TEMPERATURE AS A FUNCTION OF EXCESS AIR[1]

Figure 2-1. Relationship of temperature to excess air.[1]

TABLE 2-1. CHARACTERIZATION OF HOSPITAL WASTE[3]

Component description	HHV dry basis, kJ/kg	Bulk density as fired, kg/m^3	Moisture content of component, weight %	Heat value as fired, kJ/g
Human anatomical	18,600-27,900	800-1,200	70-90	1,860-8,370
Plastics	32,500-46,500	80-2,300	0-1	32,300-46,500
Swabs, absorbants	18,600-27,900	80-1,000	0-30	13,000-27,900
Alcohol, disinfectants	25,500-32,500	800-1,000	0-0.2	25,500-32,500
Animal infected anatomical	20,900-37,100	500-1,300	60-90	2,090-14,900
Glass	0	2,800-3,600	0	0
Beddings, shavings, paper, fecal matter	18,600-20,900	320-730	10-50	9,300-18,800
Gauze, pads, swabs, garments, paper, cellulose	18,600-27,900	80-1,000	0-30	13,000-27,900
Plastics, PVC, syringes	22,500-46,500	80-2,300	0-1	22,300-46,500
Sharps, needles	140	7,200-8,000	0-1	140
Fluids, residuals	0-23,200	990-1,010	80-100	0-4,640

Component description	HHV dry basis, Btu/lb	Bulk density as fired, lb/ft^3	Moisture content of component, weight %	Heat value as fired, Btu/lb
Human anatomical	8,000-12,000	50-75	70-90	800-3,600
Plastics	14,000-20,000	5-144	0-1	13,900-20,000
Swabs, absorbants	8,000-12,000	5-62	0-30	5,600-12,000
Alcohol, disinfectants	11,000-14,000	48-62	0-0.2	11,000-14,000
Animal infected anatomical	9,000-16,000	30-80	60-90	900-6,400
Glass	0	175-225	0	0
Beddings, shavings, paper, fecal matter	8,000-9,000	20-45	10-50	4,000-8,100
Gauze, pads, swabs, garments, paper, cellulose	8,000-12,000	5-62	0-30	5,600-12,000
Plastics, PVC, syringes	9,700-20,000	5-144	0-1	9,600-20,000
Sharps, needles	60	450-500	0-1	60
Fluids, residuals	0-10,000	62-63	80-100	0-2,000

Most chlorine in plastics or solvents in the waste feed will react to form hydrochloric acid (HCl). This HCl is an emission problem, and it can create corrosion problems downstream from the incinerator.

PRODUCTS OF THE COMBUSTION REACTION

The primary products of hospital waste incineration are combustion gases, solid residue (ash), and energy. The primary objectives of the combustion process are to generate an ash residue that is sterile (free of pathogens) and does not contain unburned, recognizable medical wastes; and to minimize air pollutants in the combustion gas stream.

The organic materials that enter the incinerator with the waste and fuel are primarily made up of carbon, hydrogen, and oxygen. Ideally, these organic materials react with oxygen in the combustion gas to form carbon dioxide (CO_2) and water vapor (H_2O). The chemical reaction for this ideal situation is

$$\underset{(C,\ H,\ O)}{\text{Organics}} + O_2 \rightarrow CO_2 + H_2O + \text{Heat}$$

This ideal reaction represents complete combustion.

However, this ideal reaction does not occur in operating waste combustion systems. Factors that lead to a less than ideal reaction are poor mixing, too little combustion air, and low temperatures. Under those conditions products of incomplete combustion are emitted with the stack gases. The most common product of incomplete combustion is CO. Concentrations of CO in the stack gas generally will increase under any of the poor combustion conditions described above. A product of incomplete combustion that often is emitted under poor mixing conditions or high temperature, low excess air conditions, is elemental carbon (or soot). The soot particles are very fine and generally result in high opacity at the combustion stack. Other products of incomplete combustion that cause concern because of their health impacts are benzene, dioxins and furans, and other hazardous organic compounds.

The waste feed also includes inorganic materials. Generally, they are not involved in the combustion reaction. The inorganic materials in the waste feed are either retained in the ash or are emitted as particulate matter in the combustion gas. Air velocities in the combustion bed are controlled to reduce the amount of inorganic material entrained (picked up by) the combustion gas and emitted with the combustion gas.

COMBUSTION INDICATORS

The information presented in the above section suggests that the following indicators can be used to monitor combustion quality.

OPACITY

The opacity of the combustion gas stream is a measure of the degree to which the stack gas plume blocks light. Opacity is primarily caused by noncombustible ash or uncombusted carbon (soot) in the flue gas. High opacities can indicate poor mixing or low levels of combustion air. High opacities also may be generated by high levels of HCl emissions or poor burner operation in the secondary chamber. If a large amount of water vapor is present in the combustion gas, the water can condense when it cools as it leaves the stack forming a dense white "steam plume." This is not an indicator of poor combustion and should not be confused with a black or white smoke plume caused by soot or acid gases.

STACK GAS O_2 CONCENTRATION

The stack gas O_2 concentration provides a measure of excess air. Hospital waste incinerators typically operate at 140 to 200 percent excess air, which roughly corresponds to 12 to 14 percent O_2 in the stack gas.

STACK GAS CO CONCENTRATION

Each combustion system has a "typical operating range" for CO. If the stack gas CO concentration goes above this typical range, combustion problems are likely.

COMBUSTION TEMPERATURE

Rapid increases or decreases in combustion gas temperature indicate potential combustion problems. Rising temperatures indicate that the heat input is increasing and/or airflow is decreasing which can lead to insufficient air for complete combustion. Falling temperatures indicate problems in sustaining combustion.

ASH COMBUSTIBLES

If an incinerator is operating properly, little organic material will remain in the ash. The extent of organics combustion is measured by the quantity of combustible materials remaining in the ash. Increases in ash combustibles indicate that bed temperatures are too low, that combustion air is not being distributed properly in the bed, or that waste retention time is too short.

REVIEW EXERCISE

1. List the three factors required for combustion.
2. Which of the following are products of complete combustion?
   Dioxins
   H_2O
   CO
   CO_2
3. The heating value of a waste required to sustain combustion without auxiliary fuel is about _____ Btu/lb.
4. List two combustion conditions that can cause high stack gas CO concentrations.
5. When the combustion air level is below stoichiometric, it is called a substoichiometric or _________-air condition.
6. All inorganic material is removed with the ash. True or False?
7. As excess air levels increase beyond stoichiometric levels, temperatures ___.
8. About 1 scf of combustion air is needed for every _____ Btu of heat input.
9. Heat input (Btu/h) = heating value (Btu/lb) x _____ _____.
10. Describe the combustion conditions that result in high opacity.
11. The most common product of incomplete combustion is _______.

1. Organic material
   Oxygen
   Heat
2. H_2O
   CO_2
3. 5,000
4. Poor mixing
   Low temperature
   Insufficient air
5. starved
6. False. Some may be emitted as particulate matter in the combustion gases.
7. decrease
8. 100
9. feed rate, lb/h
10. Poor mixing or low excess air which causes soot formation.
11. CO

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SESSION 3.
BASIC INCINERATOR DESIGN

SESSION 3. BASIC INCINERATOR DESIGN
TABLE OF CONTENTS

Page

SESSION GOAL AND OBJECTIVES.. 3-1
INTRODUCTION... 3-1
MAJOR PARTS OF AN INCINERATION SYSTEM.............................. 3-1
MULTIPLE-CHAMBER INCINERATORS...................................... 3-3
  Introduction... 3-3
  Principle of Multiple Chamber "Excess-Air" Incineration.......... 3-4
  Components of Multiple-Chamber Incinerators...................... 3-4
CONTROLLED-AIR INCINERATION.. 3-8
  Principle of Controlled-Air Incineration......................... 3-8
  Components of a Controlled-Air Incinerator....................... 3-12
ROTARY KILN.. 3-14
  Introduction... 3-14
  Principle of Operation... 3-14
  Components of a Rotary Kiln...................................... 3-14
MODE OF INCINERATOR OPERATION...................................... 3-16
  Single Batch Operation... 3-16
  Intermittent Duty.. 3-16
  Continuous Duty.. 3-17
WASTE FEED CHARGING AND ASH HANDLING SYSTEMS....................... 3-17
  Waste Feed Charging System....................................... 3-17
  Ash Removal Systems.. 3-20
COMBUSTION GAS HANDLING SYSTEM..................................... 3-21
BURNERS.. 3-23
  Forced Air Blower.. 3-24
  Fuel Train... 3-24
  Pilot and Main Burners... 3-24
  Flame Safeguard.. 3-24
WASTE HEAT BOILERS... 3-25
REFERENCES FOR SESSION 3... 3-28

LIST OF FIGURES

Figure 3-1. Major components of an incineration system.......... 3-2
Figure 3-2. In-line multiple-chamber, excess-air incinerator.... 3-5
Figure 3-3. Retort multiple-chamber, excess-air incinerator..... 3-6
Figure 3-4. Principle of controlled-air incineration............ 3-9
Figure 3-5. Control of temperature as a function of excess air.. 3-11
Figure 3-6. Major components of a controlled-air incinerator.... 3-13
Figure 3-7. Rotary kiln with auger feed......................... 3-15
Figure 3-8. Hopper/ram mechanical waste feed system............. 3-18
Figure 3-9. Hopper ram charging sequence........................ 3-19
Figure 3-10. Incinerator with staged hearth and automatic ash removal.. 3-22
Figure 3-11. Incinerator with waste heat boiler and bypass stack 3-26

SESSION 3.
BASIC INCINERATOR DESIGN

SESSION GOAL AND OBJECTIVES

GOAL

To familiarize you with

- The key components of an incinerator system;
- The different types of incineration systems; and
- The operating principles of multiple chamber excess-air and controlled (starved)-air incinerators.

OBJECTIVES

Upon completing this session, you should be able to:

1. Understand the difference between multiple chamber, controlled-air and rotary kiln incinerators;
2. Identify the type of incinerator you operate--multiple chamber, controlled air or rotary kiln;
3. Identify the type of waste charging system you use; and
4. Identify the type of ash removal system you use.

INTRODUCTION

During this session we will discuss:

1. The major components of an incineration system:
   - Waste handling and charging system;
   - Incinerator;
   - Ash removal system;
   - Auxiliary components; and
   - Control/monitoring system.
2. The three major types of incinerators used for hospital wastes and their principle of operation:
   - Multiple chamber;
   - Controlled-air; and
   - Rotary kiln.

MAJOR PARTS OF AN INCINERATION SYSTEM

Figure 3-1 depicts the major parts of an incineration system that will be discussed in this session. These are the waste charging system, the incinerator, and the ash removal system. Control and monitoring systems are discussed separately in Session 5. Add-on air pollution control systems are discussed in Session 4.

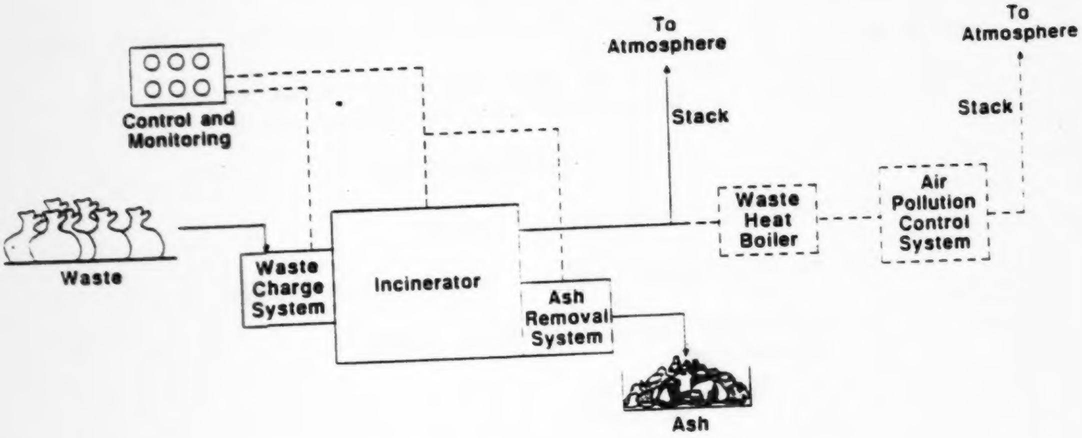

To Atmosphere
To Atmosphere
Control and Monitoring
Stack
Stack
Waste Heat Boiler
Air Pollution Control System
Waste
Waste Charge System
Incinerator
Ash Removal System
Ash

Figure 3-1. Major components of an incineration system.

It is important to think of the incinerator as a system because the design, operation, and maintenance of each part of the system affects the performance of the other parts.

For example, let's consider the waste charging system:

-- The design of the waste charging system will affect how the incinerator can be operated. If the charging system is a mechanical system with automatic controls and interlocks, then the charging rate can be automatically controlled by a timer system.
-- The operation of the waste charging system affects the performance of the incinerator; if waste is fed to the incinerator too fast, incomplete combustion and air pollution may result.
-- The maintenance of the waste charging system affects the operation of the incinerator; if the charging system breaks down, the incinerator cannot be operated.

Throughout this course, and when you operate your incinerator, you should think about all the system parts and how operation of each part affects operation and performance of the entire system.

The "heart" of the system is the incinerator, and there are three basic types of incinerators used for medical wastes:

- Multiple chamber;
- Controlled air; and
- Rotary kilns.

The following sections briefly discuss the principle of operation for each type incinerator and identify key components.

Following the sections on the major types of incinerators used for hospital waste, there is a discussion of the waste handling and charging systems, ash handling systems, and combustion air/gas handling systems typically used for the incinerators.

MULTIPLE-CHAMBER INCINERATORS

INTRODUCTION

Multiple-chamber incinerators consist of two or more combustion chambers; the primary chamber for solid phase combustion and the secondary chamber for gas phase combustion. These incinerators are often referred to as excess-air incinerators because they operate with excess air levels well above stoichiometric in both the primary and secondary combustion chambers.

The traditional designs that are used for multiple-chamber incinerators are:

the "in-line" hearth, and
the "retort" hearth.

Figure 3-2 depicts the in-line hearth design. For the in-line hearth, flow of the combustion gases is straight through the incinerator with turns in the vertical direction only (as depicted by the arrows in Figure 3-2). Figure 3-3 depicts the retort design. In the retort incinerator, the combustion gases turn in the vertical direction (upward and downward) as in the in-line incinerator, but also turn sideways as they flow through the incinerator. Because the secondary chamber is adjacent to the primary chamber (they share a wall) and the gases turn in the shape of a U, the design of the incinerator is more compact. In-line incinerators perform better in the capacity range greater than 750 lb/h (340 kg/h). The retort design performs more efficiently than the in-line design in the capacity range of less than 750 lb/h (340 kg/h). The retort design is more typically used in hospital waste applications. Multiple-chamber incinerators are frequently designed and used specifically for incinerating pathological wastes.

PRINCIPLE OF MULTIPLE CHAMBER "EXCESS-AIR" INCINERATION

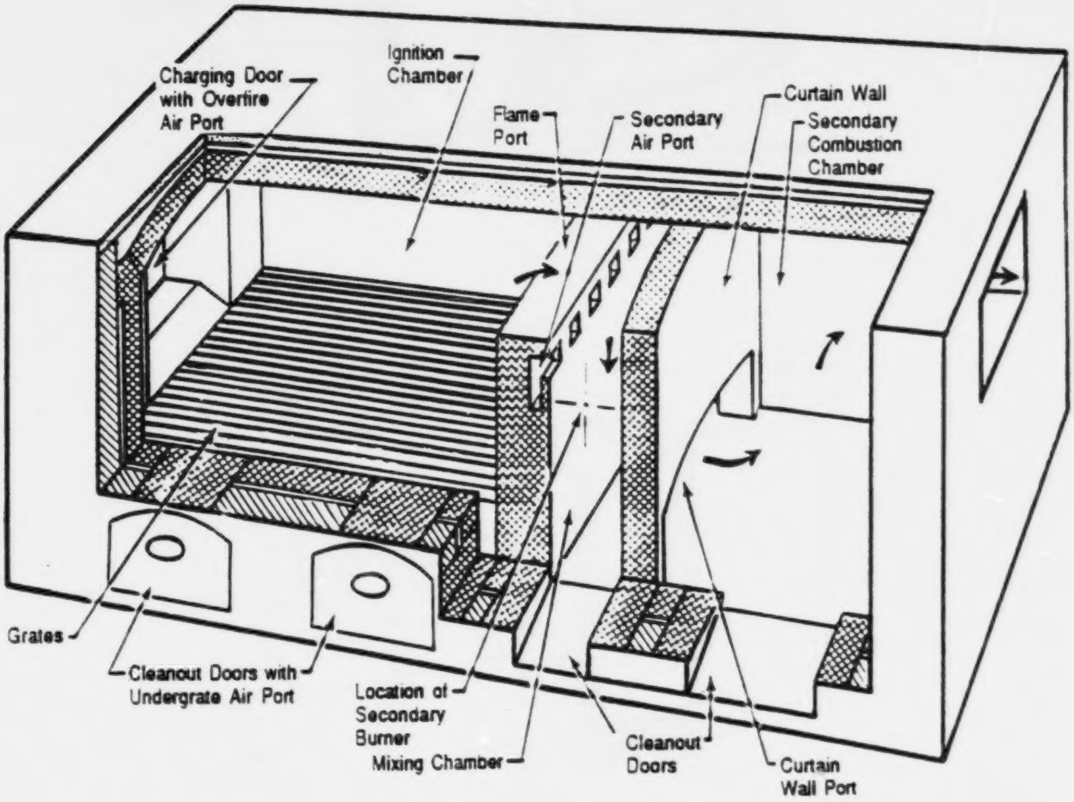
The combustion process involves two chambers. Both the primary and secondary combustion chambers are operated above stoichiometric oxygen levels.

- In the primary chamber, the waste is ignited using the primary burner. Once the waste has started burning, the burner usually shuts off because it is no longer needed.
- Moisture and the volatile part of the waste are vaporized.
- As the burning proceeds, combustion of the nonvolatile portion (fixed carbon) of the waste occurs in the primary chamber. The incinerator is designed for surface combustion of the waste. Surface combustion requires mostly overfire combustion air, rather than underfire air.
- The combustion products and vaporized gases pass from the primary chamber through the flame port to the mixing chamber.
- Secondary combustion air is added in the flame port. The design of the flame port and mixing chamber, as well as the addition of secondary air, promotes mixing.
- A secondary burner located in the mixing chamber provides additional heat to maintain sufficient combustion temperatures.
- The combustion of the gases begun in the mixing chamber continues as the gases pass through a port in the wall to the secondary or "combustion" chamber.

COMPONENTS OF MULTIPLE-CHAMBER INCINERATORS

The key components of a multiple-chamber retort incinerator are identified in Figure 3-3.

Primary Chamber. The chamber where the waste is fed and combustion begins. The chamber is operated in an "excess-air" atmosphere.



Ignition Chamber
Charging Door with Overfire Air Port
Flame Port
Secondary Air Port
Curtain Wall
Secondary Combustion Chamber
Grates
Cleanout Doors with Undergrate Air Port
Location of Secondary Burner
Mixing Chamber
Cleanout Doors
Curtain Wall Port

Figure 3-2. In-line multiple-chamber, excess-air incinerator.[1]

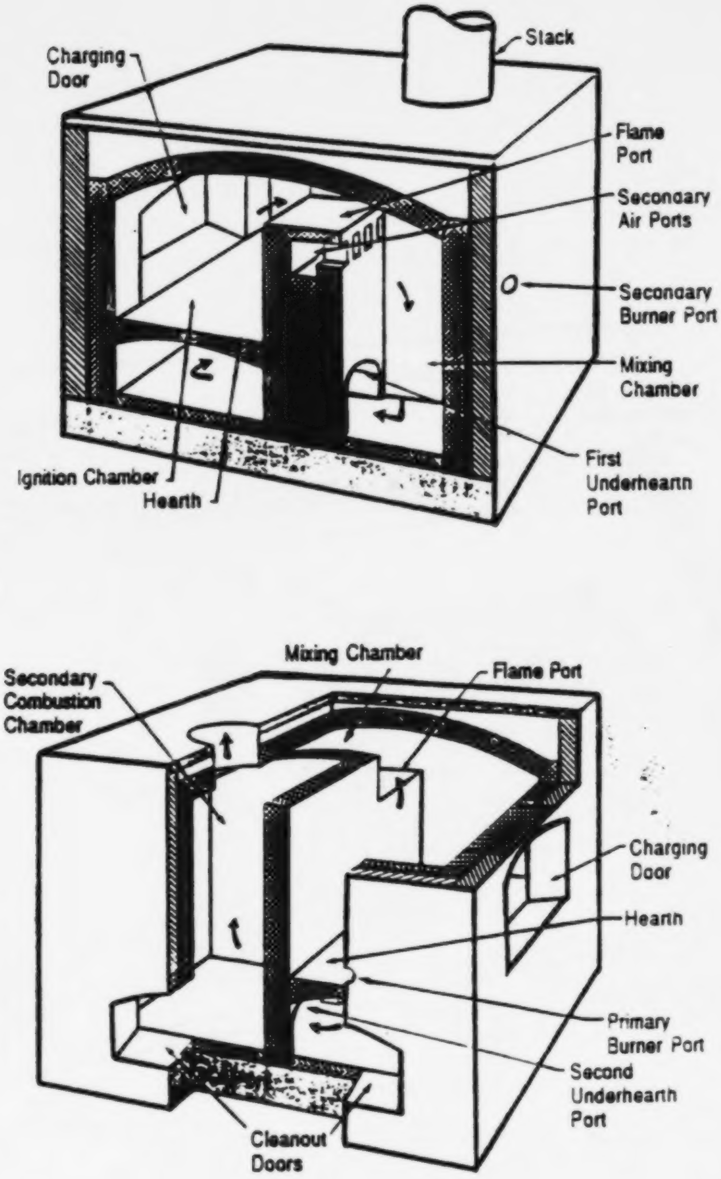

Charging Door
Stack
Flame Port
Secondary Air Ports
Secondary Burner Port
Mixing Chamber
First Underhearth Port
Ignition Chamber
Hearth
Secondary Combustion Chamber
Mixing Chamber
Flame Port
Charging Door
Hearth
Primary Burner Port
Second Underhearth Port
Cleanout Doors

Figure 3-3. Retort multiple-chamber, excess-air incinerator.

Hearth. The hearth is the surface on which the waste is placed. The he rth on a multiple-chamber incinerator is either a metal grate (F gure 3-3) or solid refractory hearth. When a grate is used, ash falls th ough the grate into the ash pit. Note: A grate will allow liquids and sm ll solid objects (such as needles) to fall through to the ash pit; cc sequently, multiple-chamber incinerators designed with a grate hearth ar not recommended for burning infectious wastes. Incinerators designed sp cifically for burning pathological wastes such as body parts and ar mals, i.e., "pathological incinerators," are always designed with solid he rths.

Ignition Burner. Fuel burner for igniting the waste.

Charging Door. Door through which waste is loaded.

Overfire Air Port. Adjustable natural draft opening which allows ov rfire combustion air to enter the primary chamber. A forced draft cc bustion air blower also may be used to provide overfire air.

Cleanout Door(s). Door(s) for removal of ash from the primary and se ondary chambers.

Mixing Chamber. Chamber located between the primary and secondary cc bustion chamber in which the combustion gases and secondary combustion ai are mixed and burning is initiated.

Flame Port. Opening between the primary chamber and mixing chamber th ough which the combustion gases pass.

Secondary Air Port. Natural draft opening through which the se ondary combustion air enters the mixing chamber. A forced air blower al o may be used to provide combustion air to the secondary chamber.

Secondary Burner. Auxiliary fuel burner for maintaining high gas te perature sufficient for complete combustion.

Secondary Combustion Chamber. Chamber where combustion of gases is cc pleted.

Stack. Duct for venting combustion gases to atmosphere.

Multiple-chamber incinerators designed specifically for pathological wa tes incorporate the following two design features:

1. The hearth in the primary chamber is solid instead of a grate; ar

2. The auxiliary burners in the primary chamber are intended for co tinuous operation.

Pathological waste is moist and contains liquids. To assure that fl ids are retained in the incineration chamber, a solid hearth is used. A aised "lip" at the door often is designed into the hearth to prevent li uids from spilling out the door during charging. Because the heating value of pathological waste is low and is not sufficient to sustain combustion, additional auxiliary burners are provided in the primary chamber to provide the heat necessary for incineration.

CONTROLLED-AIR INCINERATION

The terms used to describe various types of incinerators are quite varied. Multiple names have been used to describe the same type of incinerator. We will use the term "controlled-air" incinerator to describe one particular type of incinerator. In a controlled-air incinerator the amount and distribution of air to each combustion chamber is controlled. This type incinerator is often referred to as a "starved-air" incinerator. The term "starved-air" is derived from the principle of combustion most frequently used in this type of incinerator. The combustion air to the chamber into which the waste is fed is strictly controlled so that the amount of air present is less than that needed for complete combustion, i.e., the chamber is "starved" for air.

Controlled-air incinerators come in all sizes and shapes. Incinerators are available with design capacities ranging from 50 lb/h (23 kg/h) to 4,000 lb/h (1,800 kg/h). Some are manually controlled, and others are automatically controlled. Some use manual waste loading and ash removal, and others are fully automated.

This section presents the operating principle of controlled-air incineration and identifies the major components of a controlled-air incinerator.

PRINCIPLE OF CONTROLLED-AIR INCINERATION

Figure 3-4 is a simplified drawing of an incinerator that operates using the controlled-air principle. The principle of controlled-air combustion is summarized as follows:

- The system consists of two combustion chambers:
  - the primary chamber (also referred to as the ignition chamber); and
  - the secondary chamber (also referred to as the combustion chamber).
- The primary chamber accepts the waste, and the combustion process begins. A burner is used to ignite the waste. Once the waste has started burning, the burner usually shuts off because it is no longer needed (unless pathological wastes are being incinerated).
- The air distributed to the primary chamber is controlled so that the chamber is starved for oxygen, in other words, the chamber is operated below stoichiometric levels.
- The combustion air usually is fed to the primary chamber as underfire air--underfire air is directed "under" or through the waste bed through air inlets located near the floor or hearth of the primary chamber.

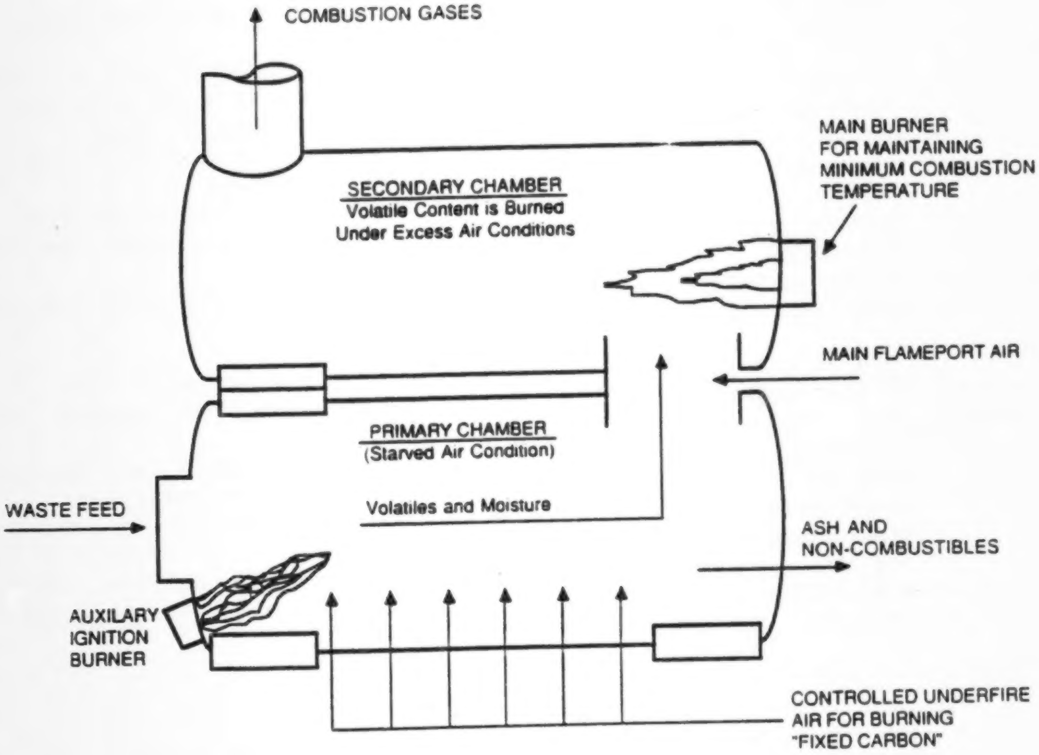

COMBUSTION GASES
MAIN BURNER
FOR MAINTAINING
MINIMUM COMBUSTION
TEMPERATURE
SECONDARY CHAMBER
Volatile Content is Burned
Under Excess Air Conditions
MAIN FLAMEPORT AIR
PRIMARY CHAMBER
(Starved Air Condition)
WASTE FEED
Volatiles and Moisture
ASH AND
NON-COMBUSTIBLES
AUXILARY
IGNITION
BURNER
CONTROLLED UNDERFIRE
AIR FOR BURNING
"FIXED CARBON"

Figure 3-4. Principle of controlled-air incineration.[2]

- Three processes occur in the primary chamber.
  - First - the moisture in the waste is vaporized; boiling a pot of water on the stove is an example of the vaporization of water.
  - Second - the volatile fraction of the waste is vaporized; when an open can of gasoline sits in the sun, the gasoline vaporizes.
  - Third - the fixed carbon remaining in the waste is burned. Fixed carbon is the nonvolatile portion of the waste. To achieve complete combustion, the fixed carbon must be burned in the primary chamber at higher temperatures and for longer times then the volatile fraction. Charcoal briquettes burning in your charcoal grill are an example of fixed carbon burning.
- The combustion gases containing the moisture and the volatile combustible materials from the primary chamber are directed to the secondary chamber.
- As the gases enter the secondary combustion chamber more air--the secondary combustion air--is added. The air is added with enough force to cause mixing of the air and the combustion gases.
- Enough air is added to the secondary chamber so that an "excess" of oxygen is available for the combustion process.
- The gas/air mixture is burned in the secondary chamber at high temperatures 1800° to 2200°F (980° to 1200°C) to promote complete combustion.
- A fuel burner is used in the secondary chamber to ensure that the high temperature is maintained.

Control of the Incinerator. The amount of air supplied to each chamber of the incinerator is used to control the combustion chamber temperature. Figure 3-5 illustrates this principle.

- The primary chamber operates in a starved-air condition. Adding more air allows more combustion and therefore increases the temperature (up to the point of maximum temperature at the stoichiometric air level).
- The secondary chamber operates in an excess-air condition. Adding more excess air (which is cold) dilutes and cools the gases and decreases the temperature.

Thus:

- The amount of air supplied to the primary chamber controls the combustion rate of the waste and the temperature of this chamber; and
- The amount of air supplied to the secondary chamber controls the temperature of this chamber and the combustion rate of the combustion gases from the primary chamber.

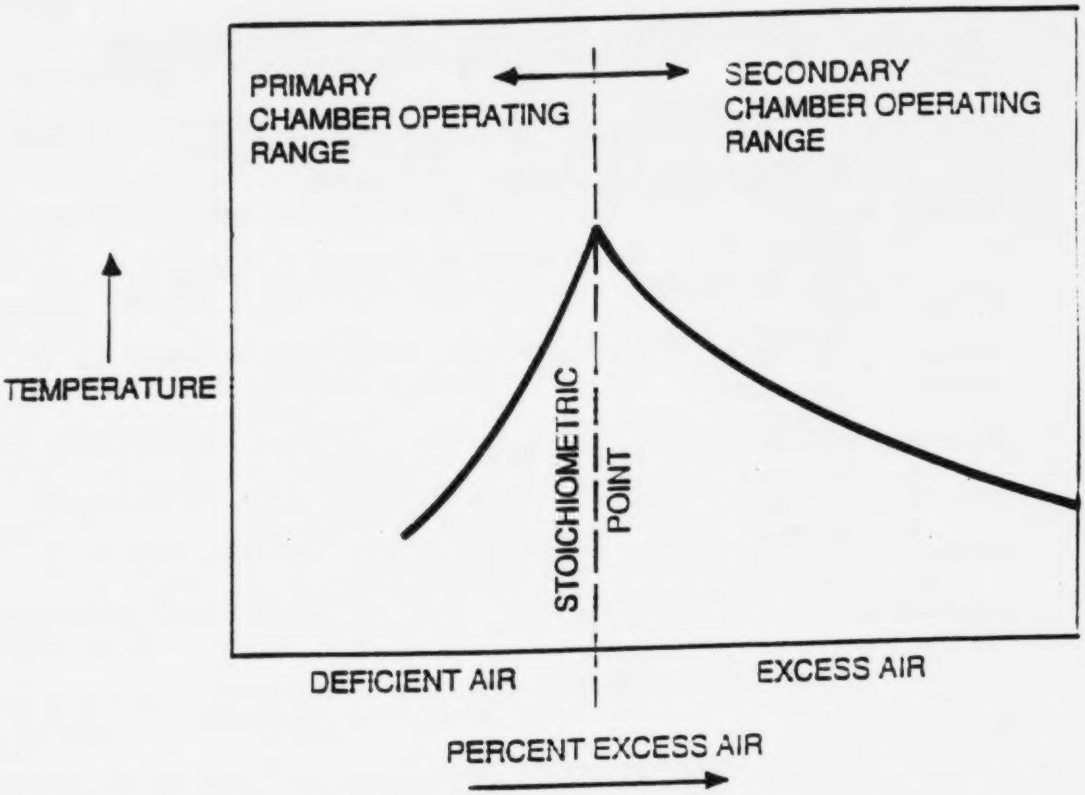


Figure 3-5. Control of temperature as a function of excess air.[3]

The control system for a controlled-air incinerator is based upon the air levels and temperatures in each chamber. Control systems are discussed in Session 5.

COMPONENTS OF A CONTROLLED-AIR INCINERATOR

Figure 3-6 presents a schematic of a controlled-air incinerator. The major components identified are:

1. Primary Chamber. The chamber where the waste is fed and combustion begins. The primary chamber operates with a "starved-air" atmosphere.
2. Primary Chamber - Combustion Air Blower. Forced air blower for providing underfire combustion air to the primary chamber.
3. Primary (Ignition) Burner. Fuel burner for preheating combustion chamber, igniting waste, and maintaining temperature in the primary chamber.
4. Charge Door. Door through which waste is loaded.
5. Ash Removal Door. Door through which ash is removed from the primary chamber.
6. Secondary Combustion Chamber. Chamber where combustion of volatile gases is completed. The secondary chamber operates with an excess-air atmosphere.
7. Secondary Combustion Air Blower. Forced air blower for providing combustion air to the secondary chamber.
8. Secondary Combustion Chamber Air Port. Port through which combustion air enters chamber and causes mixing.
9. Secondary Combustion Chamber Burner. Auxiliary fuel burner for maintaining high temperature in secondary chamber.
10. Cleanout/Inspection Doors. Doors in the secondary and primary chambers which can be opened when the incinerator is shut down to remove ash and inspect the refractory.
11. Primary Chamber Water Spray. Some manufacturers include a spray system to inject a fine water spray (mist) into the primary chamber to assist in temperature control.
12. Primary Chamber Underfire Steam Injection. Some manufacturers include systems for injecting steam into the ash.
13. Stack. Natural draft stack for venting combustion gases to the atmosphere. Because gases are hot, they rise up the stack causing a "draft" (pulling air) through the system.
14. Thermocouples. Two thermocouples located at the exit to each chamber to measure the temperature of the combustion gases.
15. View Ports. Sealed glass view ports for observing the combustion chamber during operation.
16. Control Panel. Instrument panel where the controls and the instruments for controlling and monitoring the operation are located.

The incinerator, as shown in Figure 3-6, has a hopper/ram assembly for automatically feeding the waste to the incinerator but no mechanical device for continuously removing the ash from the system. Waste feed charging systems and ash removal systems are discussed later in this section.

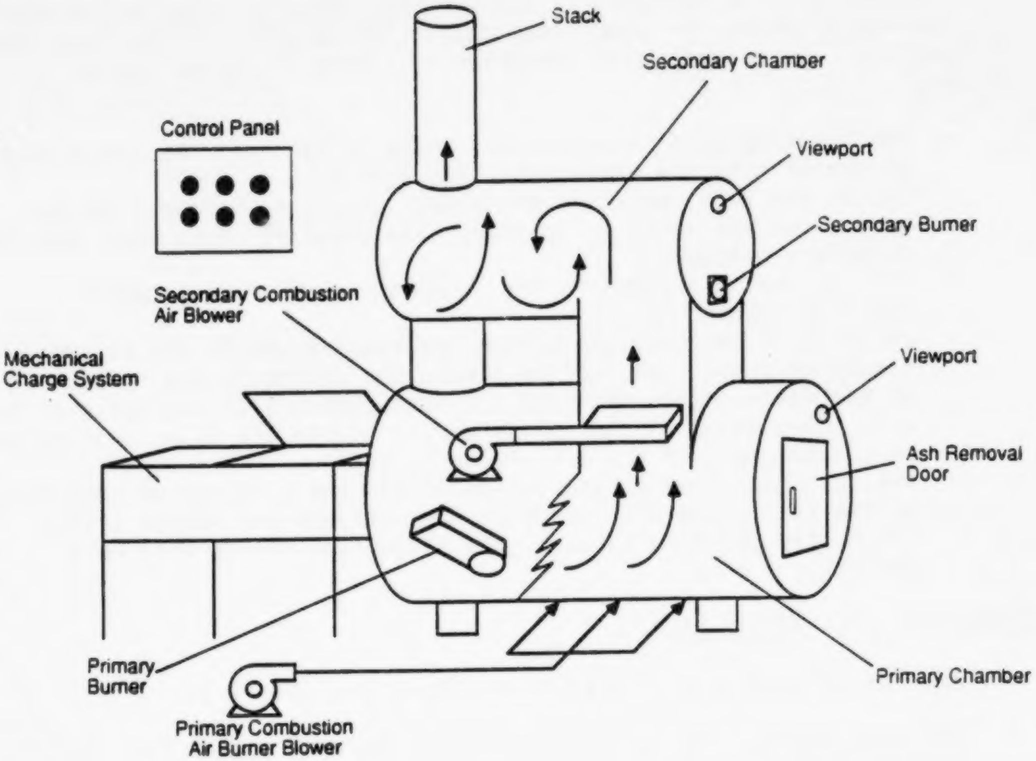

Stack
Secondary Chamber
Control Panel
Viewport
Secondary Burner
Secondary Combustion Air Blower
Mechanical Charge System
Viewport
Ash Removal Door
Primary Burner
Primary Chamber
Primary Combustion Air Burner Blower

Figure 3-6. Major components of a controlled-air incinerator.

ROTARY KILN

INTRODUCTION

Figure 3-7 is a schematic of a rotary kiln. A rotary kiln also uses the concept of two stage combustion and has two combustion chambers. The primary chamber is a horizontal cylindrical chamber which is slightly inclined and rotates, hence the name "rotary kiln." The secondary chamber is usually cylindrical in shape--much like the secondary chambers described for controlled-air incinerators--or is box-like as depicted in Figure 3-7.

PRINCIPLE OF OPERATION

A rotary kiln is designed to operate continuously. The incinerator must include a system for continuous waste feed to the kiln and continuous ash removal. The principle of operation of a kiln is summarized as follows:

- The rotating kiln is inclined. Waste is fed into the higher end of the kiln by the mechanical feed system.
- Inside the kiln, moisture and volatiles are vaporized from the waste, and the waste is ignited. The volatile gases pass into the secondary chamber.
- Air and heat are added in the secondary chamber to promote complete combustion.
- As the kiln rotates, the solids are tumbled within the kiln and slowly move down the incline toward the discharge end. Tumbling of the waste within the kiln provides exposure of the waste to the air. Combustion of the solids occurs within the kiln, and the ash is discharged into the ash removal system.
- The residence time of the solids within the kiln can be controlled by the kiln's speed of rotation (revolutions per minute [rpm]). The faster the kiln rotates, the faster the solids will move through the kiln.

COMPONENTS OF A ROTARY KILN

The key parts of a rotary kiln are shown in Figure 3-7:

Charging System. Mechanical waste feed charging system for continuously feeding waste to the kiln.

Kiln. The rotating kiln is the primary combustion chamber. The waste is fed into this kiln and ignited. Traditionally, the kiln operates with an excess-air atmosphere. However, some manufacturers now have rotary kilns designed to operate with a substoichiometric atmosphere in the kiln; these kilns use special seals and air injection schemes.

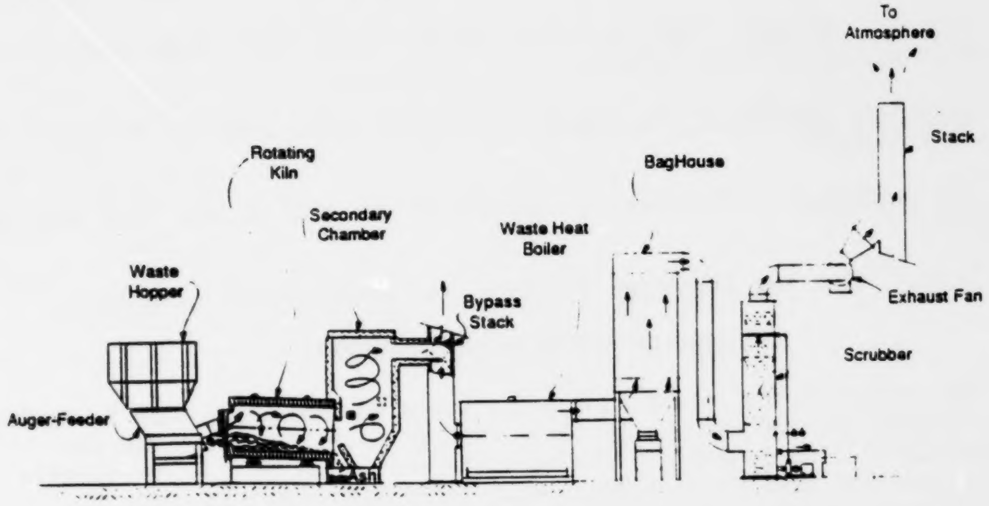

To Atmosphere
Stack
Rotating Kiln
BagHouse
Secondary Chamber
Waste Heat Boiler
Waste Hopper
Bypass Stack
Exhaust Fan
Scrubber
Auger-Feeder
Ash

Figure 3-7. Rotary kiln with auger feed.[4]

Kiln Drive. The kiln is rotated by a drive motor and gear system.

Primary Burner. The primary burner ignites the waste and provides additional heat input to the primary chamber, as necessary.

Primary Combustion Air Blower. Provides combustion air for the primary chamber.

Kiln Seals. Sealing rings to minimize air in-leakage between the rotating kiln and the kiln end plates.

Secondary Chamber. Chamber where final combustion of gases occurs.

Secondary Burner. Auxiliary fuel burner to maintain temperature of the secondary combustion chamber.

Secondary Combustion Air Blower. Provides combustion air for the secondary chamber.

Ash Container. Container for collecting ash exiting the lower end of the kiln.

Stack. Vent for discharge of combustion gases to the atmosphere.

MODE OF INCINERATOR OPERATION

The design of the incinerator and associated equipment--such as waste feed charging and ash removal systems--must be consistent with how the incinerator will be operated. The opposite also is true--how you operate your incinerator must be consistent with the design features. For the purposes of discussion, we can define three basic modes of incinerator operation.

1. Single batch;
2. Intermittent duty; and
3. Continuous duty.

SINGLE BATCH OPERATION

Single batch operation means the incinerator is loaded with a batch of waste, sealed, and turned on. After combustion is completed, the incinerator is allowed to cool and the ash is removed. Usually, ash is not removed until the next day.

INTERMITTENT DUTY

Intermittent duty means that the incinerator is intermittently loaded with batches of waste, one after another, over a period of time, usually one to two work shifts. The batches might be fed at routine intervals--such as every 5 minutes for 8 hours or might be fed at uneven intervals, whenever waste is available. In any event, the incinerator must be shut down to remove ash from the system; thus, its operation is intermittent.

CONTINUOUS DUTY

Continuous duty means the incinerator can be continuously operated 24 hours per day. The system is designed so that ash is removed while the incinerator is in operation and the incinerator does not have to be shut down. The waste feed charging system and ash removal system are very important parts of this incineration system.

WASTE FEED CHARGING AND ASH HANDLING SYSTEMS

WASTE FEED CHARGING SYSTEMS

There are many different ways to "feed" the incinerator. The incinerator should be fitted with a waste feed charging system that is consistent with its mode of operation and capacity. Manual and mechanical waste feed systems will be discussed.

Manual Feed. This means you load the waste directly into the incinerator. This approach is applicable only for single batch units or smaller intermittent feed units. A safety hazard exists when waste is fed manually into an operating incinerator.

Mechanical Feed. When mechanical feed is employed, some type of mechanical device is used to charge the waste to the incinerator. The most common mechanical feed system is the hopper ram assembly, which frequently is called a ram feed system. Figure 3-8 shows a hopper/ram system. In a mechanical hopper/ram feed system:

- Waste is manually placed into a charging hopper, and the hopper cover is closed.
- A fire door isolating the hopper from the incinerator opens.
- The ram moves forward to push the waste into the incinerator.
- The ram reverses to a location behind the fire door.
- After the fire door closes, a water spray cools the ram, and the ram retracts to the starting position.
- The system is ready to accept another charge.

Figure 3-9 depicts this sequence. The entire hopper/ram charging sequence normally is timed and controlled by an automatic sequence. The sequence can be activated by the operator (push start button) or for larger, fully automated incinerators may be activated at preset intervals by an automatic timer.

The simplest hopper ram assembly requires the operator to manually load the waste into the hopper. However, some systems are designed to make loading the hopper easier. An example of a way to make hopper loading easier is a system where the hopper is located low enough so that all the operator has to do is tilt a cart containing the waste so that the waste falls into the hopper. One fully automated system uses a "cart

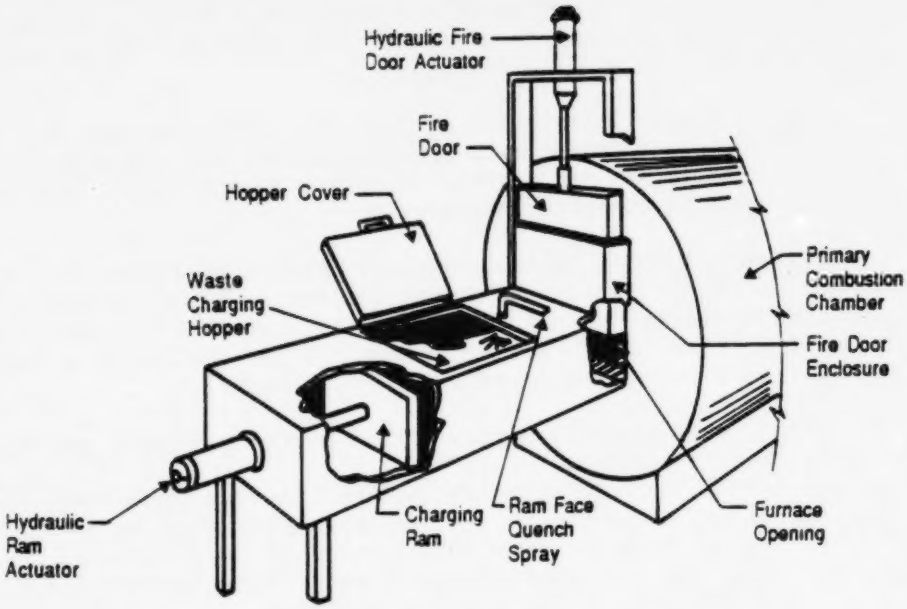

Hydraulic Fire Door Actuator
Fire Door
Hopper Cover
Waste Charging Hopper
Primary Combustion Chamber
Fire Door Enclosure
Hydraulic Ram Actuator
Charging Ram
Ram Face Quench Spray
Furnace Opening

Figure 3-8. Hopper/ram mechanical waste feed system.[5]

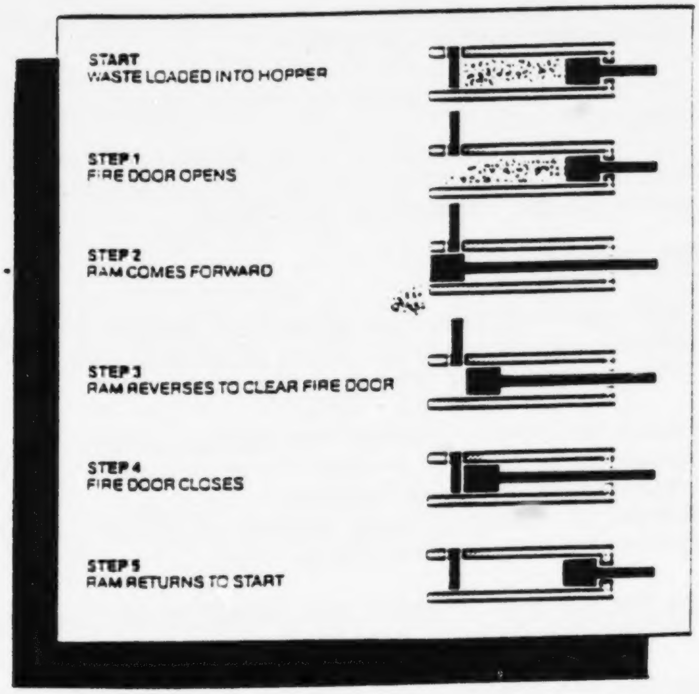

START
WASTE LOADED INTO HOPPER
STEP 1
FIRE DOOR OPENS
STEP 2
RAM COMES FORWARD
STEP 3
RAM REVERSES TO CLEAR FIRE DOOR
STEP 4
FIRE DOOR CLOSES
STEP 5
RAM RETURNS TO START

Figure 3-9. Hopper ram charging sequence.[6]

dumper" which automatically picks up a cart full of waste and dumps the waste into the hopper.

Another type of mechanical feed system which has been used for rotary kilns is an auger-feeder. The auger-feeder utilizes an auger (screw-type device) at the bottom of the waste hopper to continuously feed the waste into the kiln. However, these systems may cause problems with medical wastes because red bags can break. Breaks may result in liquids leaking from the feed system or in fugitive emissions of volatile organic materials.

Mechanical charging systems have several advantages over manual handling and charging:

- They provide added safety to the operating personnel by preventing heat, flames, and combustion products from escaping the incinerator during charging.
- They limit ambient air infiltration when charging a controlled-air incinerator, thus, there is little impact on the combustion rate.
- They enable incinerators to be automatically charged with smaller batches of waste at regulated time intervals; this improves operation and combustion efficiency.

ASH REMOVAL SYSTEMS

The ash remaining from the combustion process must be removed from the incinerator and disposed of in an acceptable manner. The ash is removed either manually or mechanically.

- Manual removal is typical for smaller units.
- Manual or mechanical removal is practiced for medium-sized, intermittent-duty incinerators.
- Mechanical semicontinuous removal of ash is necessary for continuous-duty incinerators.

Manual Ash Removal. Manual ash removal means that you remove the ash from the incinerator using a rake or shovel.

Mechanical Ash Removal. Continuous operation of an incinerator requires some type of mechanical system for removing the ash while the incinerator is operating. The mechanical system includes three major components:

1. A means of moving the ash to the end of the incinerator hearth--usually an ash transfer ram or series of transfer rams;
2. A collection device or container for the ash as it is discharged from the hearth; and
3. A transfer system to move the ash from the collection point.

Manual ash removal is used for most multiple-chamber incinerators. For controlled-air incinerators using mechanical ash removal, the ram used for waste charging often is used for pushing the ash to the discharge end of the hearth. As each new waste charge is pushed into the incinerator, it pushes the waste bed on the hearth forward towards the discharge end. Each repetitive charge continues to push a portion of the waste bed towards the discharge end where it falls into a drop chute or water quench pit.

Figure 3-10 depicts an incinerator that has stepped hearths and several individual ash transfer rams. This system is often used in larger incinerators. Each hearth has its own ash ram and the waste is pushed from one hearth to the other by activating each ram in series, starting at the discharge end of the hearth. In other words:

- The ash on the last hearth (3) is discharged by ram No. 3.
- Ram No. 2 activates and pushes the waste on hearth No. 2 to hearth No. 3.
- Ash ram No. 1 activates and pushes the waste on hearth No. 1 to hearth No. 2.
- Finally, a new charge is added to hearth No. 1.

A major advantage to this type of system is that when the waste is pushed from one hearth to the next, the waste bed is mildly disturbed and redistributed which provides some degree of "mixing" of the waste and promotes more complete combustion. Another advantage is that the underfire air to each hearth usually can be controlled separately, which allows for greater combustion control.

After the ash drops from the hearth, some means of collecting and transporting the ash is required. One type of collection system uses an ash bin sealed directly to the discharge chute or positioned within an air-sealed chamber below the hearth. A door or gate which seals the chute is opened at regular intervals to allow the ash to drop into the collection bin. When the bin is filled, the seal-gate is closed and the bin is removed and replaced with an empty bin. In the second method, the ash is discharged into a water pit. The ash discharge chute is extended into the water pit so that an air seal is maintained. The water bath quenches the ash as the ash is collected. A mechanical device, either a rake or drag conveyor system, is used to intermittently or continuously remove the ash from the quench pit. The excess water is allowed to drain from the ash as it is removed from the pit, and the wetted ash is discharged into a collection container.

COMBUSTION GAS HANDLING SYSTEM

All incinerators must have a system for moving combustion air and combustion gases through the incinerator system and for controlling the air flow. Three basic types of systems are typically used for hospital waste incinerators. These are:

- natural draft;
- induced draft; and

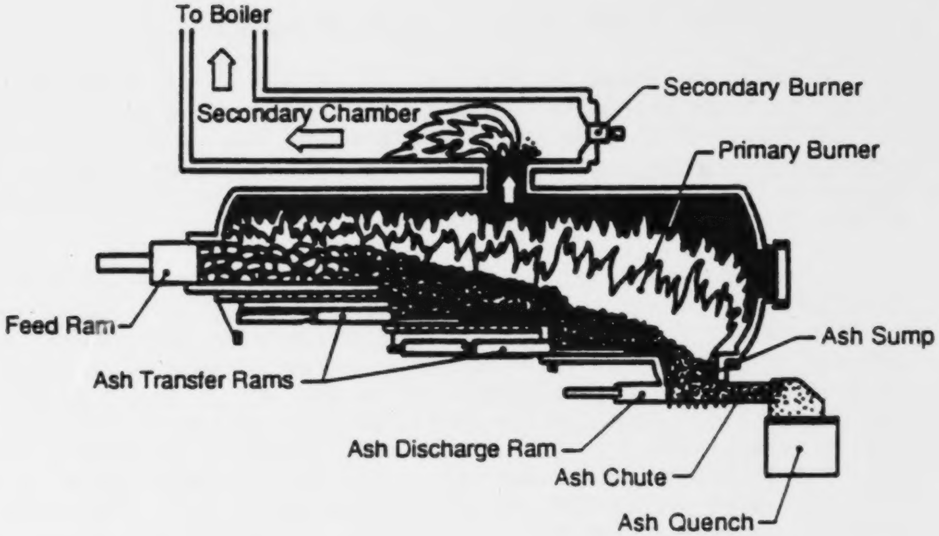

To Boiler
Secondary Burner
Secondary Chamber
Primary Burner
Feed Ram
Ash Sump
Ash Transfer Rams
Ash Discharge Ram
Ash Chute
Ash Quench

Figure 3-10. Incinerator with staged hearth and automatic ash removal.[7]

- balanced draft (a combination of induced draft and forced draft)

Draft is the difference between the pressure within the incinerator and the pressure in the atmosphere. When the pressure inside the incinerator is lower than the outside air pressure (i.e., negative pressure), air tends to flow into the incinerator. Incinerators are equipped with stacks to produce the "draft" necessary to move combustion air into the incinerator and to discharge the combustion gases to the atmosphere. The height of the stack and the difference in temperature between the combustion gases and the outside air creates a natural draft. Because the incinerator is at a lower pressure than the outside air, combustion air is pulled into the incinerator.

Incinerators that have heat recovery boilers or air pollution control (APC) systems usually use an induced draft system. When a boiler or APC system is added to the incinerator, the resistance to airflow is increased (that is, airflow is "blocked") and natural draft is no longer sufficient to move air through the system. A fan is added at the end of the system to "induce" a draft, or pull the gases through the system.

Many incinerators use forced draft fans or "combustion air blowers" to push the combustion air into the incinerator. In a balanced draft system, a forced draft fan is used to push (or blow) combustion air into the incinerator and an induced draft fan (or the natural draft stack) is used to pull the combustion gas through the incinerator and exit from the stack. The draft is balanced so that the incinerator is maintained at a slightly negative pressure. This negative pressure presents emissions from leaking from the combustion chamber.

Mechanisms for controlling incinerator draft are discussed in Session 5.

BURNERS

The burners on a hospital waste incinerator provide the heat needed to ignite the waste initially and to sustain combustion of the waste charged. The burners may be either oil-fired or gas-fired (natural gas or propane) and are designed to provide a rated heat input expressed in BTU/h. The heat input rate for the burners on your incinerator will depend on the type of incinerator at your facility, the number of burners, and the heating value of the waste burned. Most incinerators have a single burner in the secondary chamber that burns the combustion gases from the primary chambers. However, the primary chamber may have more than one burner, especially if the incinerator has been designed to burn pathological waste only.

The components of a burner system include a forced-air blower, a fuel train, pilot and main burners, and most importantly a flame safeguard system. The following paragraphs give a brief description of these components.

FORCED AIR BLOWER

The forced-air blower provides the combustion air needed to burn the oil or gas fuel and, if oil is used, the atomizing air. A single forced-air blower in conjunction with regulatory values may be used to supply air to the different burners or each burner may have a separate air blower. When the burner is first turned on, the blower comes on and purges the burner of any volatile gas or oil residues that may have built up since the last burn. This is a safety feature.

FUEL TRAIN

The fuel train is the series of components that controls the flow of fuel to the burner. The fuel train set up for gas and oil burners is basically the same. Each fuel train has a pressure gauge, a manual shutoff valve, and a solenoid shut-off valve. The only difference between the gas and oil fuel trains is the device used to control fuel flow; the oil fuel train utilizes a needle flow valve while the gas fuel train utilizes a gas orifice union. The manual shut-off valves must be open before the burners are turned on. The solenoid valves are safety valves which close off the fuel supply if the burners do not light or if the air supply for combustion is lost.

PILOT AND MAIN BURNERS

Each burner is equipped with both a pilot and main burner. The pilot is lit first, and, once a flame is detected, the fuel supply to the main burner is opened allowing the pilot to light the main burner. Proper operation of the burners is best achieved by looking at the burner flame pattern through the viewports in the incinerator wall or in the burner itself. Some burners are equipped with an observation port to view the main flame and another to view the pilot flame. Gas-fired burners have a blue flame while oil-fired burners have a luminous yellow flame. The flame pattern will likely vary with the type of burner. However, the length of the flame should be such that the flame touches the waste but does not impinge directly on the refractory floor or wall.

FLAME SAFEGUARD

The device which controls the burner ignition process is called the flame safeguard. When the burner is first started, the burner blower starts and when it reaches full speed, a purge timer starts. When the purge timer times out, the flame safeguard energizes the pilot relay that opens the pilot fuel supply and ignitor. When the pilot lights, a flame detector (either an ultraviolet scanner [gas or oil] or flame rod circuit [gas only]) detects the pilot flame and causes the main flame relay to activate the fuel supply to the main burner. The pilot then ignites the main burner. The flame detector continues to operate and shuts the burner down if the main burner fails. Additionally, if the air supply is lost, both pilot and flame relays shut off the fuel supply. The pilot usually is ignited for no more than 15 seconds (interrupted pilot). If the main burner does not ignite during the pilot ignition period, the flame safeguard system shuts the entire system down by closing the solenoid shut-off valve and turning off the burner blower.

WASTE HEAT BOILERS

The heat generated during incineration can be recovered and used to generate hot water or steam in a waste heat boiler. Addition of a waste heat boiler to an incinerator has several impacts on the incineration system. One impact of adding a boiler to the system is that fan induced draft fan must be added to the system in order to move air through the system. An emergency bypass stack is another feature that normally would be added to an incinerator when a waste heat boiler (or air pollution control system) is added to the incinerator system. Since the boiler causes a resistance (blockage to airflow) in the system if the induced draft fan stops, pressure will build up in the incinerator because the hot gases cannot escape quickly enough. The bypass stack is added to allow a route for the hot gases to escape should the fan fail. In other words, it allows the incinerator to go back to a natural draft system. The bypass stack also is used in cases where the boiler must be bypassed for some reason (for example, loss of water flow to the boiler causing heat buildup). The bypass stack usually contains a damper valve in the stack to control direction of the gas flow or a cap on top of the stack to prevent air from being pulled into the system when the fan is operating. When the "bypass" must be activated, the damper, or cap, is opened. The bypass is usually activated automatically by some type of sensor; for example, if the fan speed falls below a preset level, the bypass opens. Figure 3-11 is a schematic of an incinerator with a waste heat boiler, induced draft fan, and emergency bypass stack.

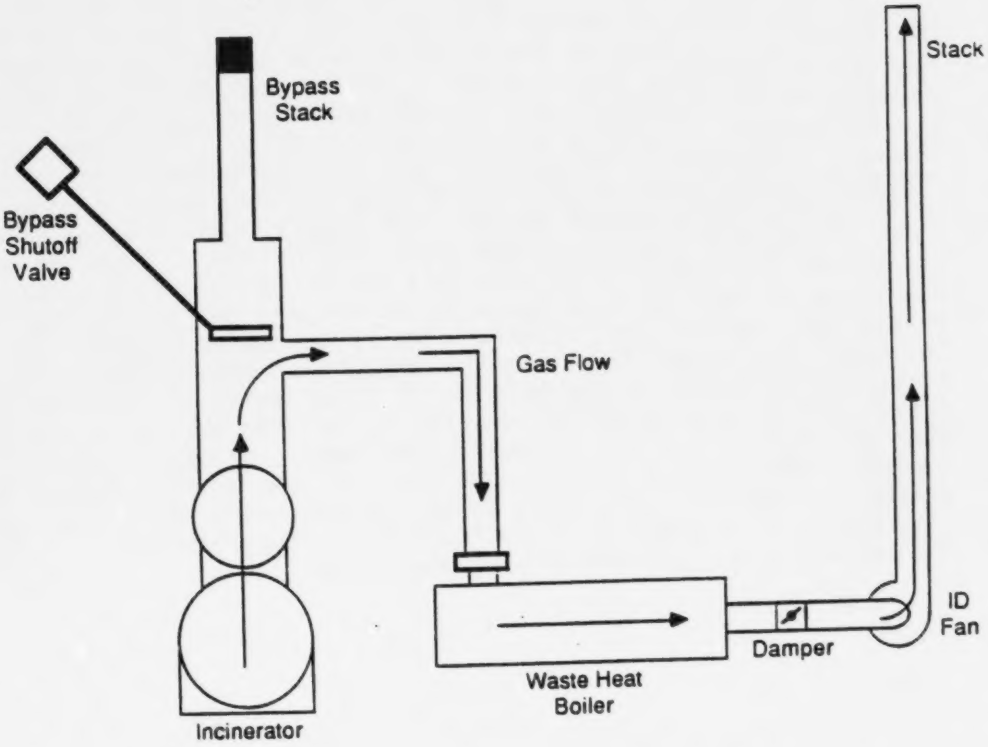

Bypass Stack
Bypass Shutoff Valve
Stack
Gas Flow
ID Fan
Damper
Waste Heat Boiler
Incinerator

Figure 3-11. Incinerator with waste heat boiler and bypass stack.[2]

REVIEW EXERCISE

---

1. Which type of incinerators listed below use combustion in two chambers?

   a. Controlled-air incinerators
   b. Multiple-chamber incinerators
   c. Rotary kilns
   d. All of the above
   e. a and b

1. d. All of the above

2. The unique feature of the controlled-air incineration principle is:
   a. Large incinerators can be built
   b. Combustion is controlled by limiting the air in the primary chamber to below stoichiometric; combustion occurs in two stages
   c. The combustion chambers are shaped like cylinders

2. b. The primary chamber operates with starved air and combustion occurs in two stages.

3. Continuous-duty incinerators *must* include which of the following important features not normally included in intermittent-duty incinerators?

   a. Automatic waste feed
   b. Continuous ash removal
   c. Temperature monitors

3. b. Continuous ash removal

4. An incineration *system* includes which of the following:

   a. Waste feed charging system
   b. Incinerator
   c. Ash removal system
   d. Control and monitoring system
   e. All of the above
   f. b and d

4. e. All of the above

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SESSION 4.
AIR POLLUTION CONTROL EQUIPMENT DESIGN AND FUNCTIONS

SESSION 4. AIR POLLUTION CONTROL EQUIPMENT DESIGN AND FUNCTIONS

TABLE OF CONTENTS

Page

SESSION GOAL AND OBJECTIVES.................................... 4-1

INTRODUCTION... 4-1

WET SCRUBBERS - GENERAL.. 4-1
  Pollutants Controlled.. 4-1
  Pollutant Collection Principles.............................. 4-1
  Types of Wet Scrubbers Used on Hospital Incinerators......... 4-2

PACKED-BED SCRUBBERS... 4-2
  Pollutants Controlled.. 4-2
  Description of Packed-Bed Scrubber........................... 4-2
  How Does a Packed-Bed Scrubber Work?......................... 4-2

VENTURI SCRUBBERS.. 4-6
  Pollutants Controlled.. 4-6
  Description of Venturi Scrubber.............................. 4-8
  How Does a Venturi Scrubber Work?............................ 4-8

SPRAY TOWERS... 4-8
  Pollutants Controlled.. 4-11
  Description of Spray Tower Scrubber.......................... 4-11
  How Does a Spray Tower Scrubber Work?........................ 4-11

FABRIC FILTERS... 4-11
  Pollutants Controlled.. 4-11
  Pollutant Collection Principles.............................. 4-11
  Description of a Pulse-Jet Fabric Filter..................... 4-13
  How Does a Pulse-Jet Fabric Filter Work?..................... 4-13

DRY SCRUBBERS - GENERAL.. 4-14
  Pollutants Controlled.. 4-14
  Pollutant Collection Principles.............................. 4-14
  Types of Dry Scrubbers Used on Hospital Incinerators......... 4-14

SPRAY DRYERS... 4-14
  Description of Spray Dryers.................................. 4-14
  How Does a Spray Dryer Work?................................. 4-14

DRY INJECTION.. 4-17
  Description of Dry Injection................................. 4-17
  How Does Dry Injection Work?................................. 4-17

ELECTROSTATIC PRECIPITATORS.................................... 4-19
  Pollutants Controlled.. 4-19
  Pollutant Collection Principles.............................. 4-19
  Description of a Single-Stage, Hot-Side, Plate ESP........... 4-19
  How does an ESP Work?.. 4-21

REFERENCES FOR SESSION 4....................................... 4-27

SESSION 4. AIR POLLUTION CONTROL EQUIPMENT DESIGN AND FUNCTIONS

LIST OF FIGURES

Page

Figure 4-1. Impaction.. 4-3
Figure 4-2. Absorption... 4-4
Figure 4-3. Countercurrent-flow packed-bed scrubber............ 4-5
Figure 4-4. Spray venturi with rectangular throat.............. 4-7
Figure 4-5. Cyclonic mist eliminator........................... 4-9
Figure 4-6. Countercurrent-flow spray tower.................... 4-10
Figure 4-7. Pulse-jet baghouse................................. 4-12
Figure 4-8. Components of a spray dryer absorber system......... 4-15
Figure 4-9. Spray dryer adsorber vessel........................ 4-16
Figure 4-10. Components of a dry injection absorption system..... 4-18
Figure 4-11. Alternative dry injection absorption system......... 4-20
Figure 4-12. Discharge and collection plate electrodes for a plate ESP...................................... 4-22
Figure 4-13. Single-stage, hot-side plate ESP................... 4-23

SESSION 4.
AIR POLLUTION CONTROL EQUIPMENT DESIGN AND FUNCTIONS

SESSION GOAL AND OBJECTIVES

GOAL

To familiarize you with the components and the functions of the various types of air pollution control systems that are found on hospital incinerators.

OBJECTIVES

Upon completing this session, you should be able to:

1. Identify the type of air pollution control system used on your incinerator;
2. Name the air pollutants that your air pollution control system is intended to control;
3. Understand the basic principles that account for pollutant collection and removal;
4. Identify the major components of your air pollution control system; and
5. List the functions of each major component.

INTRODUCTION

During this session we will discuss the various types of APCS usually used or expected to be extensively used in the future on hospital waste incinerators. The APCS to be discussed are listed below.

- Wet scrubbers
  - Packed-bed scrubbers
  - Venturi scrubbers
  - Spray towers
- Fabric filters
- Dry scrubbers
  - Spray dryers
  - Dry injection
- Electrostatic precipitators

WET SCRUBBERS - GENERAL

POLLUTANTS CONTROLLED

The pollutants controlled by wet scrubbers include particulate matter and the acid gases (HCl and SO_2). Because of the variations in design some units are more effective for particulate matter while others are primarily intended for acid gas control.

POLLUTANT COLLECTION PRINCIPLES

- Particulate matter - collection mechanism is primarily impaction on wetted surfaces or in liquid droplets. Figure 4-1 shows impaction.
- Gases - gaseous collection is through diffusion and absorption. Figure 4-2 shows absorption.
- After capture of the pollutants in the liquid, the liquid droplets must be separated from the clean gas stream.

TYPES OF WET SCRUBBERS USED ON HOSPITAL INCINERATORS

- Packed-bed scrubbers
- Venturi scrubbers
- Spray towers

PACKED-BED SCRUBBERS

Figure 4-3 shows a packed-bed scrubber.

POLLUTANTS CONTROLLED

- Packed-bed scrubbers are used primarily for acid gas control.
- While packed-bed scrubbers remove some particulate matter, they have a low collection efficiency for fine particulates.

DESCRIPTION OF PACKED-BED SCRUBBER

Packed-bed scrubbers consist of:

- A cylindrical shell to house the scrubbing media;
- Packing media and supporting plates;
- Liquid spray nozzles to distribute the scrubbing liquid;
- Demister pads to remove liquid droplets from the clean flue gas; and
- An induced draft fan for moving the flue gas through the scrubber.

The packing media is composed of 1- to 3-inch (2.5- to 7.6-cm) diameter plastic shapes that are intended to maximize the surface area.

HOW DOES A PACKED-BED SCRUBBER WORK?

The scrubbing liquid used is important.

- With water as the scrubbing liquid there is removal of soluble gases. HCl is highly soluble in water and is efficiently captured in wet scrubbers.

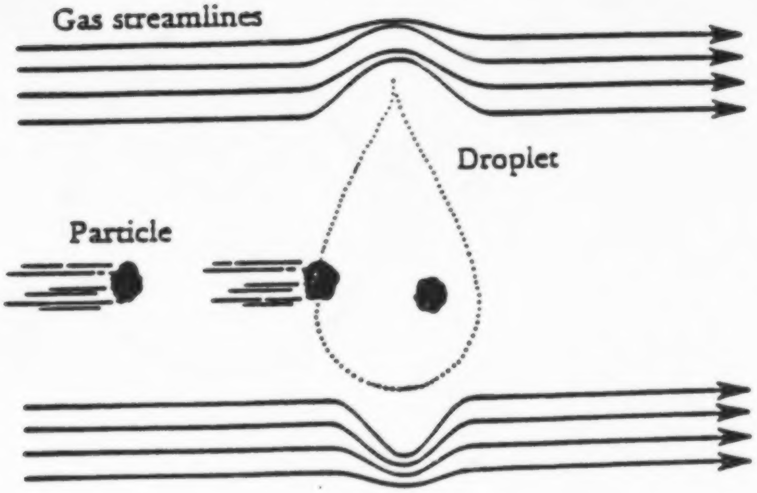
Gas streamlines
Droplet
Particle

Figure 4-1. Impaction.[1]

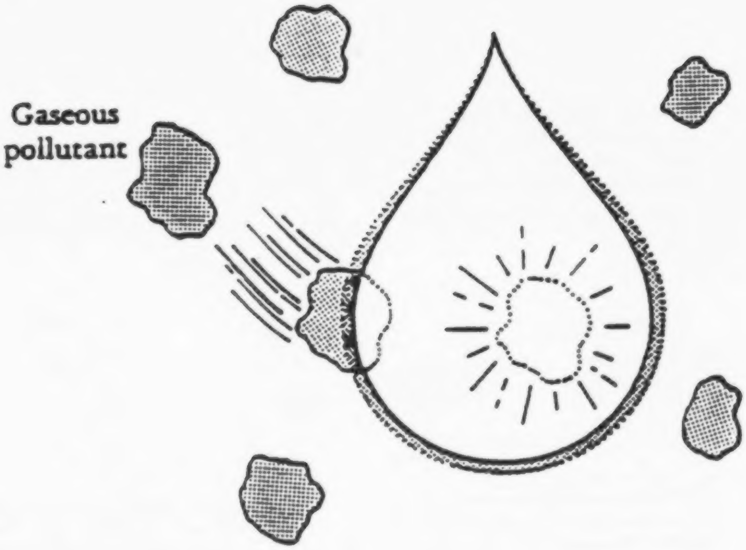
Gaseous pollutant

Figure 4-2. Absorption.[1]

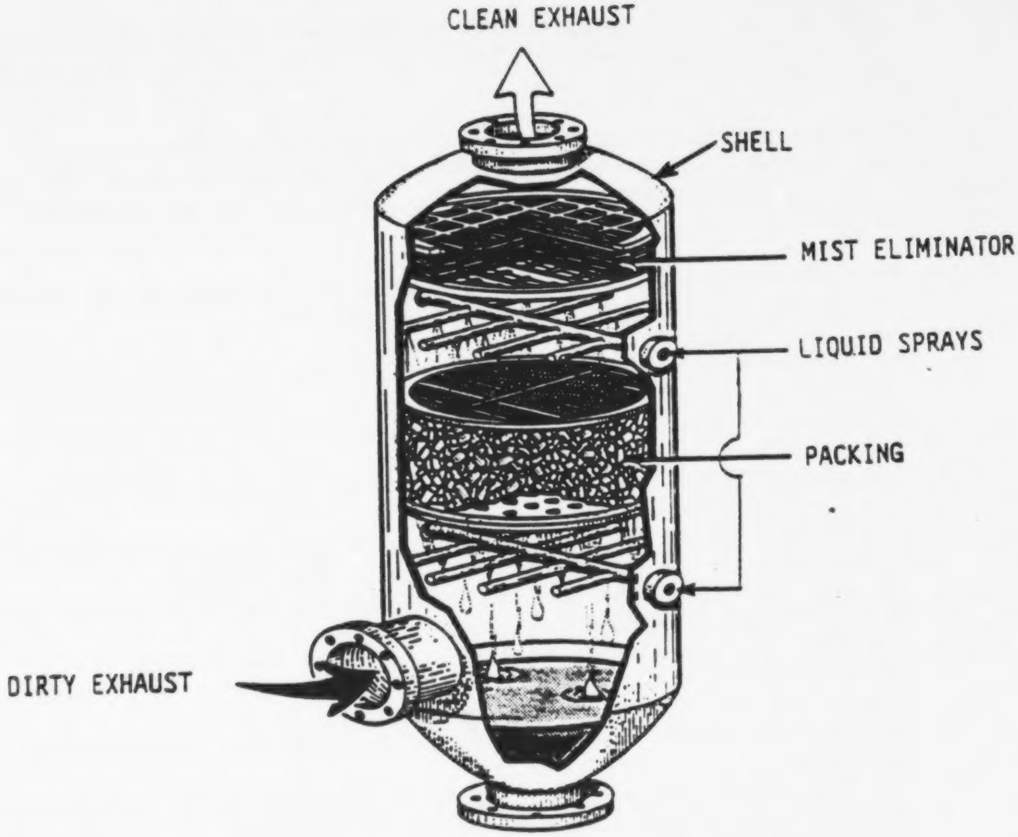
CLEAN EXHAUST
SHELL
MIST ELIMINATOR
LIQUID SPRAYS
PACKING
DIRTY EXHAUST

Figure 4-3. Countercurrent-flow packed-bed scrubber.[1]

- Alkaline (caustic) materials, such as lime, are added to the water to neutralize the acids collected in the scrubbing liquid. The liquid is neutralized to reduce corrosion of equipment and keep the pH (a measure of the water's acidity) of the water discharge within acceptable ranges required by wastewater treatment facilities.
- Addition of alkaline materials is needed to achieve significant reductions of acid gases, such as SO_2 which are less soluble in water than is HCl.

Packed-bed scrubbers are designed to maximize the surface area of the liquid/gas interface to increase opportunities for absorption of the acid gases at low fan energy costs. Relatively large amounts of scrubbing liquid per unit of flue gas are used.

- Packed-bed scrubbers intended for acid gas control use an alkaline scrubbing liquid; example materials are:
  - -- Lime (CaO);
  - -- Sodium hydroxide (NaOH); and
  - -- Sodium carbonate (Na_2CO_3).
- Scrubbing liquid is sprayed onto the packing media from the top and bottom.
- The liquid passes downward due to gravity, wetting the surface of the packing media.
- The dirty flue gases enter the bottom of the scrubber and travel countercurrent (opposite) to the flow of the liquid.
- The wet surface of the packing media creates a large surface area of liquid/gas interface for absorption.
- The acid gases are absorbed and captured in the liquid.
- The acid gases react with the alkaline materials in the scrubbing liquid and are neutralized.
- Particulate matter is collected in the scrubbing liquid through impaction.
- The flue gases pass out the top of the scrubber unit through the demister pads which remove any entrained droplets of liquid that may contain absorbed acid gases and particulate matter.
- The dirty scrubbing liquid containing the collected particulate, acid gas/sorbent reaction products, and the unreacted sorbent materials passes out the bottom of the scrubber and is recycled or sent to wastewater treatment.

VENTURI SCRUBBERS

Figure 4-4 shows a venturi scrubber.

POLLUTANTS CONTROLLED

Venturi scrubbers are high-energy scrubbers used for the control of fine particulate emissions. Hydrochloric acid gas, if present, also is controlled by a venturi scrubber.

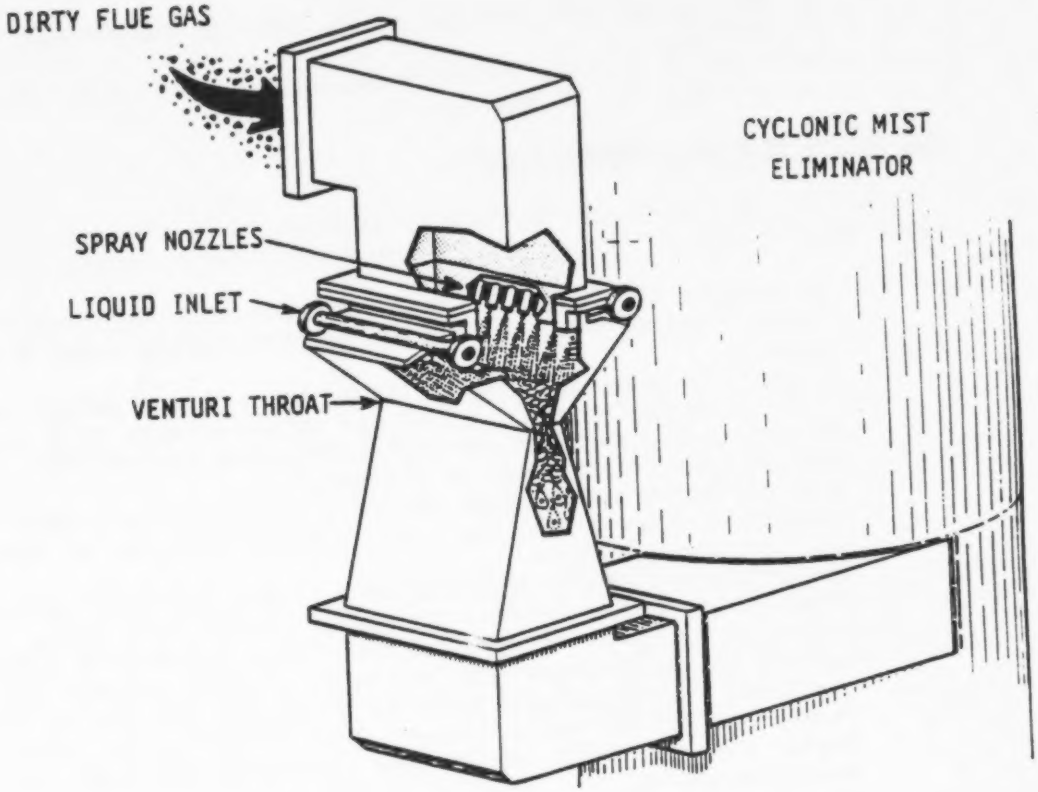
DIRTY FLUE GAS
CYCLONIC MIST ELIMINATOR
SPRAY NOZZLES
LIQUID INLET
VENTURI THROAT

Figure 4-4. Spray venturi with rectangular throat.[1]

DESCRIPTION OF VENTURI SCRUBBER

- A venturi scrubber consists of:
  - -- A constriction in the ductwork referred to as a venturi throat;
  - -- Spray nozzles at the entrance to the venturi throat that supply the scrubbing liquid, usually water;
  - -- A cyclonic mist eliminator for removing entrained water droplets; and
  - -- An induced draft fan for moving the flue gas through the scrubber
- Some venturi scrubbers have an adjustable throat that can be used to vary the size of the opening.

HOW DOES A VENTURI SCRUBBER WORK?

Venturi scrubbers are designed to maximize turbulence and mixing of water droplets and dirty flue gas to improve pollutant capture efficiency.

- The venturi throat has the smallest cross-sectional area in the ductwork and consequently the gas has the highest speed at this location.
- As the flue gases speed up at the entrance to the venturi section, water is injected into the flue gas stream through spray nozzles or through the force of the high speed gases passing over water running down on the sides of the venturi.
- The high gas speeds through the constricting throat create turbulence which breaks the water droplets into smaller fine droplets and causes mixing.
- Collection efficiency increases with higher gas speeds and turbulence; however, higher gas speeds require more energy. The amount of energy is measured as the change in pressure across the venturi or the pressure drop in inches of water column. For scrubbers with adjustable throats, decreasing the size of the throat opening increases pressure drop and collection efficiency.
- Higher pressure drops require more fan energy and result in higher operating costs.
- The water droplets, containing the captured particulate matter, are separated from the clean gas stream in the cyclonic mist eliminator using centrifugal force. Figure 4-5 shows a cyclonic mist eliminator.
- The dirty scrubber water is sent to wastewater treatment. Some facilities may recycle the scrubber water after it goes through a settling tank. If your facility has such a recycle system, the solids content and pH of the recycle waters must be controlled.

SPRAY TOWERS

Figure 4-6 shows a spray tower scrubber.

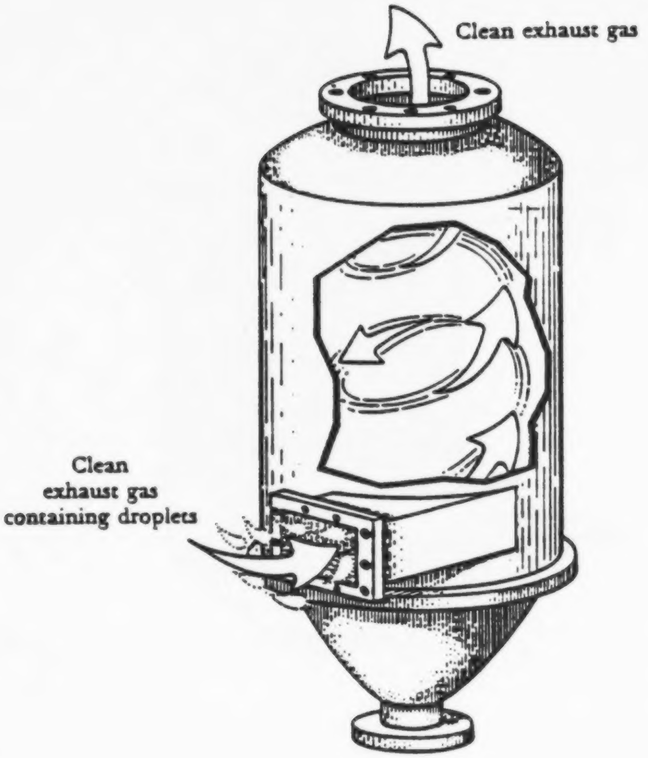
Clean exhaust gas
Clean
exhaust gas
containing droplets

Figure 4-5. Cyclonic mist eliminator.[1]

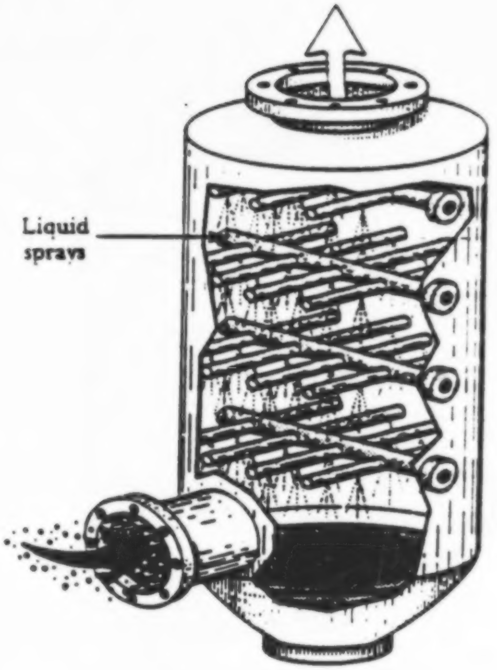
Liquid sprays

Figure 4-6. Countercurrent-flow spray tower.[1]

POLLUTANTS CONTROLLED

Spray towers are low-energy scrubbers used to control large-particle emissions.

- Spray towers are only effective for relatively large particles and are limited in applicability to multiple chamber incinerators.
- Controlled-air incinerators have inherently low particulate mass emission rates and fine particle size distributions that cannot be effectively controlled by spray towers.

DESCRIPTION OF SPRAY TOWER SCRUBBER

Spray towers are relatively simple scrubbers consisting of:

- A hollow cylindrical steel vessel; and
- Spray nozzles for injecting the scrubbing liquid.

HOW DOES A SPRAY TOWER SCRUBBER WORK?

Spray towers are designed to use many spray nozzles to create a large amount of fine liquid droplets for impacting and capturing particulate matter.

- The dirty exhaust gas enters the bottom of the scrubber and travels upward.
- Water droplets are sprayed downward by a series of spray nozzles designed to cover the entire cross-sectional area of the scrubber.
- The cleaned exhaust gas exits out the top of the scrubber.

FABRIC FILTERS

Figure 4-7 shows a pulse-jet fabric filter.

POLLUTANTS CONTROLLED

Fabric filters are designed to remove solid particulate matter from the flue gas stream by filtering the flue gas through fabric bags.

- Fabric filters are especially effective at removing fine particulate matter.
- When used with a dry scrubber (see next section), the fabric filter cake will help remove acid gases from the flue gases.

POLLUTANT COLLECTION PRINCIPLES

- Particulate - the dirty flue gases are passed through fabric bags which filter out the particulate matter creating a "cake" (i.e., a coating) of collected particulate matter on the bag that further increases filtration. The principle is very similar to that of a household vacuum cleaner.

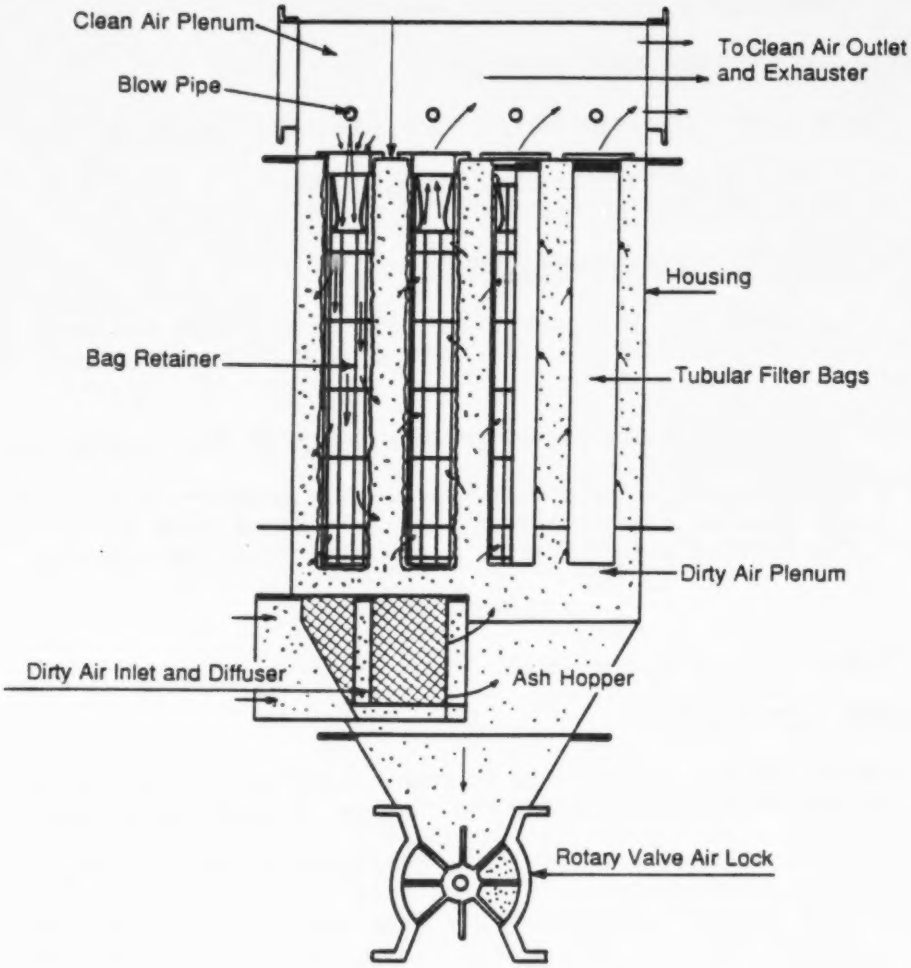
Clean Air Plenum
To Clean Air Outlet and Exhauster
Blow Pipe
Housing
Bag Retainer
Tubular Filter Bags
Dirty Air Plenum
Dirty Air Inlet and Diffuser
Ash Hopper
Rotary Valve Air Lock

Figure 4-7. Pulse-jet baghouse.[2]

- Acid gases - when used with dry scrubbers (see next section), the alkaline material injected by the scrubber is collected in the filter bag along with the pollutants. As the acid gases pass through the cake they react with the alkaline material, form solid salts, and are captured.

DESCRIPTION OF A PULSE-JET FABRIC FILTER

- Pulse jets are one of three fabric filter types classified by bag cleaning technique. Pulse-jet fabric filters are used on hospital waste incinerators.
- A pulse-jet fabric filter consists of:
  - -- Dirty air inlet and a plate (diffuser) with holes in it that uniformly distributes the flue gas;
  - -- A dirty air chamber or plenum which contains the fabric bags;
  - -- A tube sheet, with holes for each bag, which supports the bags and separates the dirty air plenum from the clean air plenum;
  - -- The tubular filter bags with supporting wire frame bag retainers;
  - -- The bag cups and venturi's to which the individual bags are attached and which inject the pulse of cleaning air into the bags;
  - -- The air compressor which supplies the compressed air for cleaning the bags;
  - -- The ash hopper which holds the collected particulate after it is cleaned from the bag; and
  - -- A rotary valve air lock which discharges the ash from the hopper.

HOW DOES A PULSE-JET FABRIC FILTER WORK?

The openings in the mesh weave of a fabric filter bag are relatively large and can only capture large particles. Actual filtration of fine particles is performed by the cake of filtered-out material that builds up on the bag surface.

- The dirty flue gas enters through the air inlet at the bottom of the unit and is distributed through the diffuser.
- The dust-laden gas flows upward through the dirty air plenum and is filtered through the bags with the filtered-out dust cake forming on the outside of the bags.
- On a timed frequency or at a pre-determined pressure drop, the bags are cleaned.
- The bags are cleaned by a blast of compressed air injected into the top of the bag tube.
- The air blast creates a shock wave that travels down the bag, fracturing the filter cake.
- The filter cake falls into the ash hopper at the bottom of the unit and is removed through the rotary valve air lock.

DRY SCRUBBERS - GENERAL

POLLUTANTS CONTROLLED

Dry scrubbers remove acid gases, primarily HCl and SO_2.

POLLUTANT COLLECTION PRINCIPLES

Dry scrubbers inject alkaline sorbent materials into the dirty flue gas. The acid gases begin to react with the alkaline sorbents to produce solid particulate salts that are collected by a particulate control device, usually a fabric filter (see previous section), that follows the dry scrubber. The unreacted sorbent is also captured on the fabric filter cake where additional acid gas reacts with the sorbent and is captured.

TYPES OF DRY SCRUBBERS USED ON HOSPITAL INCINERATORS

- Spray dryers
- Dry injection

SPRAY DRYERS

DESCRIPTION OF SPRAY DRYERS

- Figure 4-8 shows a schematic of a spray dryer system. Figure 4-9 shows an internal view of the spray dryer absorber vessel.
- The primary components of a spray dryer system are:
  - -- Lime slaker, if pebble lime is purchased;
  - -- Sorbent mixing tank;
  - -- Sorbent feed tank;
  - -- Atomizer feed tank;
  - -- Rotary atomizers or air atomizing nozzles;
  - -- Spray dryer absorber reaction vessel;
  - -- Solids recycle tank; and
  - -- Particulate control device.

HOW DOES A SPRAY DRYER WORK?

Spray dryers are designed to spray an alkaline slurry of sorbent material into the hot flue gases where the acid gases are absorbed into the slurry droplets and reacted with the alkaline material to form solid particle reaction products.

- Spray dryer facilities usually purchase pebble lime (CaO) for use.
- The pebble lime is converted to calcium hydroxide [$Ca(OH)_2$] by the addition of water in the slaker.
- The calcium hydroxide is mixed with water in the mixing tank to produce a slurry containing 5 to 20 percent solids.
- The slurry is stored in the feed tank and is transferred to the atomizer feed ta[illegible] immediately prior to use.
- The atomizers pr[illegible]e small droplets of slurry that are injected into the absorbe[illegible]action vessel.

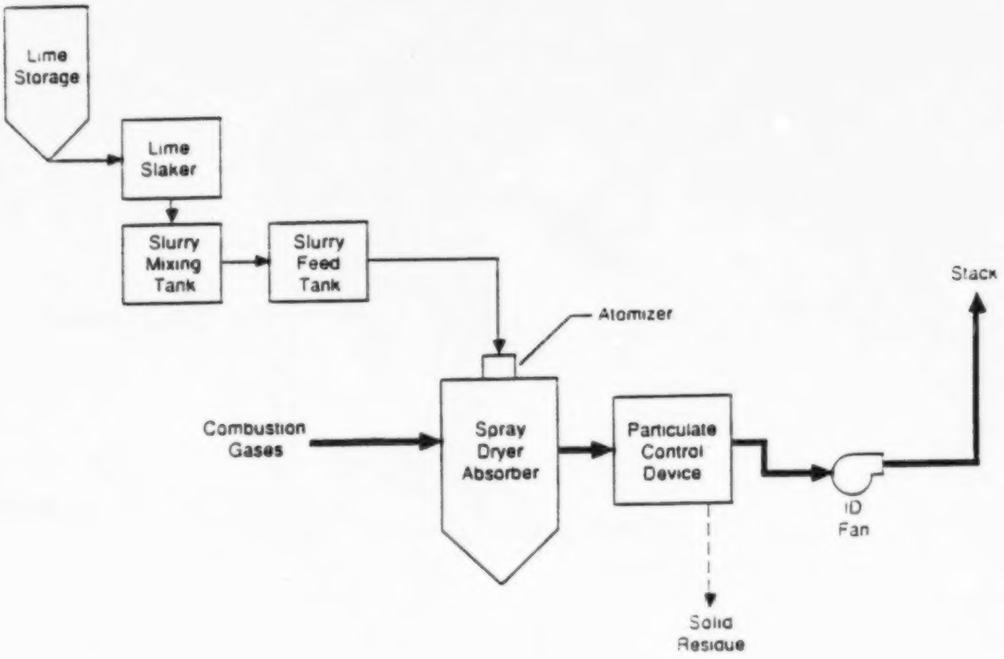
Lime Storage
Lime Slaker
Slurry Mixing Tank
Slurry Feed Tank
Atomizer
Stack
Combustion Gases
Spray Dryer Absorber
Particulate Control Device
ID Fan
Solid Residue

Figure 4-8. Components of a spray dryer absorber system.

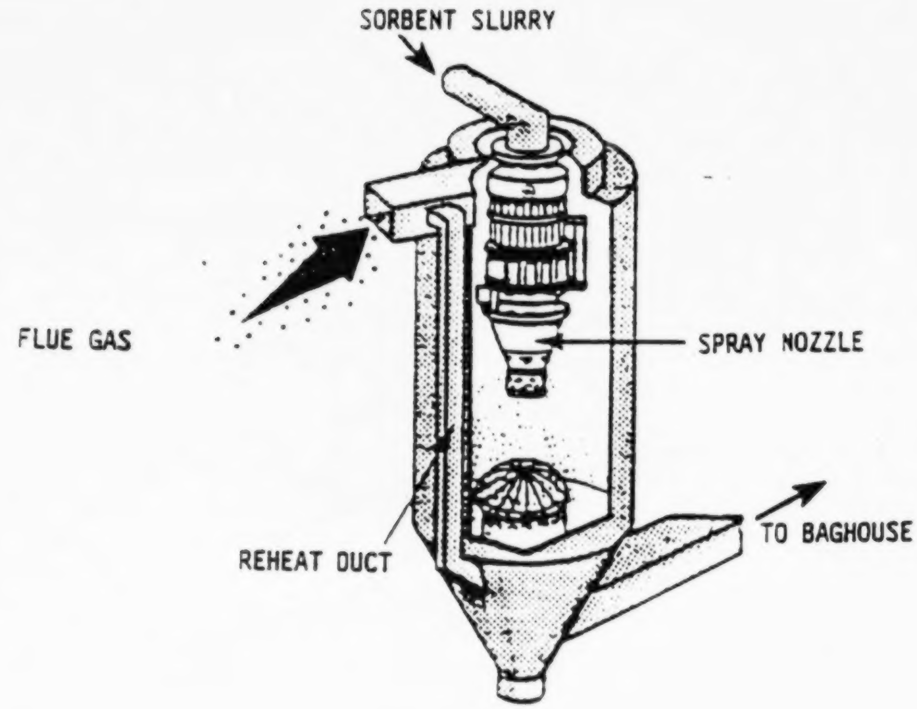
SORBENT SLURRY
FLUE GAS
SPRAY NOZZLE
TO BAGHOUSE
REHEAT DUCT

Figure 4-9. Spray dryer absorber vessel.

- The alkaline sorbents in the slurry react with the acid gases producing $CaCl_2$ and $CaSO_4$ solid salts.
- The hot flue gases dry the moisture from the slurry and the reacted and unreacted sorbent either is entrained in the flue gas stream or drops to the bottom of the reaction vessel.
- The entrained sorbent and reaction products are carried to the particulate control device where they are captured.
- The sorbent and reaction products that drop to the bottom of the reaction vessel can either be disposed of or retained in the solids recycle tank for recycle back to the mixing tank.

DRY INJECTION

Figure 4-10 shows a dry injection system schematic.

DESCRIPTION OF DRY INJECTION

Dry injection systems consist of:

- Dry sorbent storage tank;
- Blower and pneumatic line for transfer of the sorbent;
- Injector;
- Expansion/reaction chamber (optional); and
- Particulate control device (fabric filter or ESP) for collection of the dry sorbent.

In some cases, the expansion/reaction chamber shown in Figure 4-10 is not included.

HOW DOES DRY INJECTION WORK?

Dry injection systems are similar to spray dryers with the exception that the sorbent materials are injected into the flue gases as a dry powder. Since there is no moisture, the reaction rate is slower than with a spray dryer.

- The dry injection system uses finely divided alkaline sorbent material, usually calcium hydroxide or sodium bicarbonate, with the approximate consistency of talcum powder.
- The dry sorbent material is blown down the pneumatic line to the flue gas exhaust duct.
- Transfer through the pneumatic line provides fluidization and breaks up any clumps of sorbent.
- The sorbent is injected into the flue gas duct which creates turbulence that results in mixing of the sorbent with the flue gas.
- Absorption of the acid gases by the sorbent begins in the flue gas ductwork.
- An expansion/reaction chamber may be included to increase the residence time of the gases in the system, allowing more time for the reaction to occur.

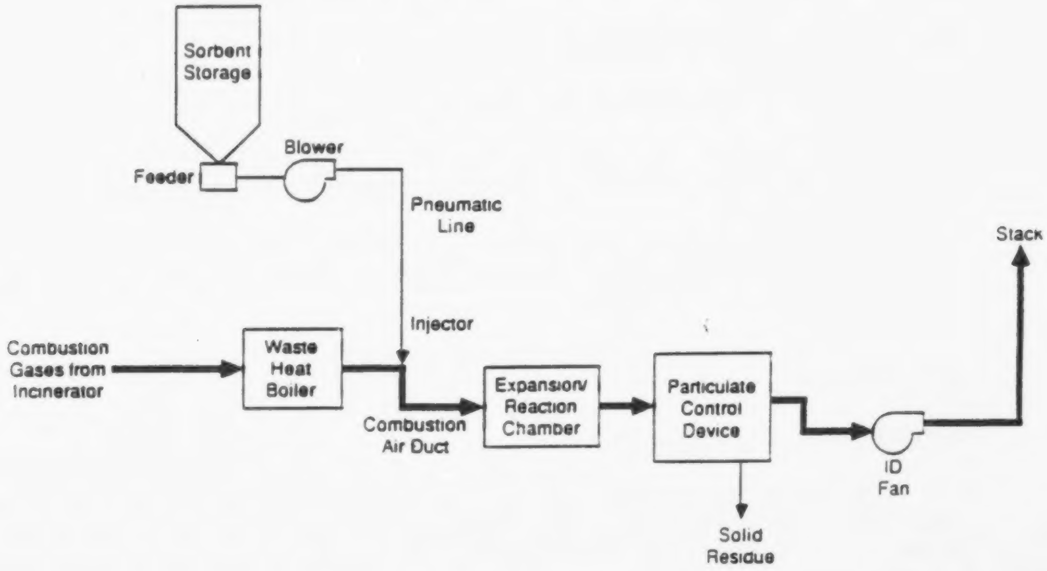
Sorbent Storage
Feeder
Blower
Pneumatic Line
Injector
Combustion Gases from Incinerator
Waste Heat Boiler
Combustion Air Duct
Expansion/ Reaction Chamber
Particulate Control Device
Solid Residue
ID Fan
Stack

Figure 4-10. Components of a dry injection absorption system.

- The sorbent and reaction products are carried by the flue gas to the particulate control device where the solids are collected.
- If a fabric filter is used as the particulate control device, acid gas removal may be further enhanced by reaction with the sorbent collected in the filter cake.

Figure 4-11 presents a schematic of another variation on the dry injection system. In this system, the dry alkaline sorbent is injected directly into a contactor/reactor vessel rather than into the duct.

ELECTROSTATIC PRECIPITATORS

POLLUTANTS CONTROLLED

Electrostatic precipitators (ESP's) are used to remove particulate matter from flue gas streams. They have been used for over 50 years on many industrial processes.

POLLUTANT COLLECTION PRINCIPLES

Particulate matter must first be charged with electricity before it can be collected in an ESP. Once the particles or liquid aerosols that makeup the particulate matter are charged, they move towards an oppositely charged surface because of electrostatic attraction (opposite charges attract each other, the same charges repel each other). The collected particles are removed by rapping or washing the collecting surface. This charging, collecting, and removal process is commonly referred to as precipitation.

DESCRIPTION OF A SINGLE-STAGE, HOT-SIDE, PLATE ESP

- ESP's can be classified according to a number of design features. These features include the method of charging (single-stage or two-stage), the method of particle removal from collection surfaces (wet or dry), the temperature of operation (cold-side or hot side), and the structural design and operation of the discharge electrodes (tubular or plate). The ESP's likely to be used on medical waste incinerators are single-stage, hot-side, plate ESP's and are discussed here.
- Most ESP's used to reduce particulate matter emissions from boilers and other industrial processes are single-stage ESP's. These units use very high voltage to charge particles. The particles, once charged, move in a direction perpendicular to the gas flow and are collected on the oppositely charged collection surface. Because particle charging and collection occurs in the same stage, these ESP's are called single stage ESP's.
- Collected particles are removed from the unit by rapping the collection electrodes or by spraying water on the electrodes to wash the particles away.

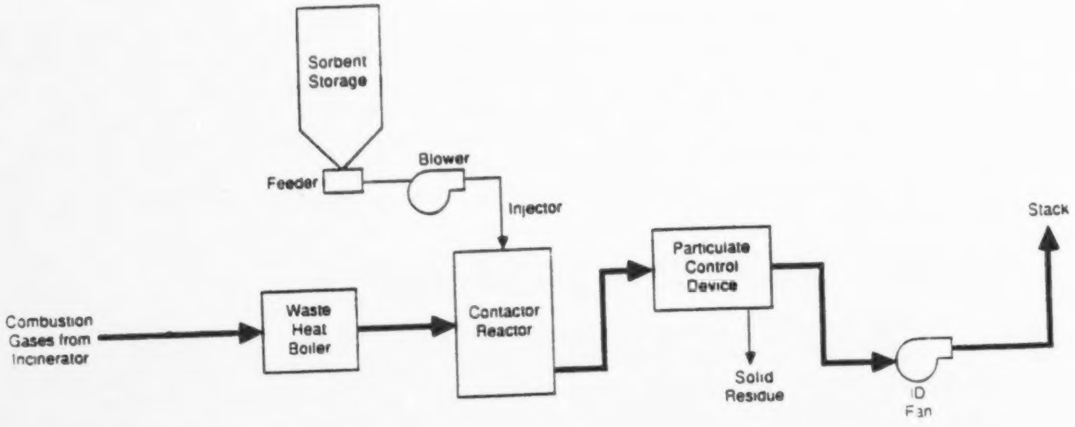
Sorbent Storage
Feeder
Blower
Injector
Stack
Particulate Control Device
Combustion Gases from Incinerator
Waste Heat Boiler
Contactor Reactor
Solid Residue
ID Fan

Figure 4-11. Components of a dry injection adsorption system.

- ESP's are grouped according to the temperature of the flue gas entering the unit. Therefore, the ESP's used on medical waste incinerators are likely to be hot-side units. These ESP's are larger than cold-side ESP's because the higher gas temperature makes the volume of gas treated larger.
- ESP's use either flat plates or cylindrical tubes to collect particulate matter. Most ESP's use plates as collection electrodes. In this arrangement, dirty gas flows into a chamber consisting of a series of small diameter discharge electrodes (wires) especially spaced between rows of plates. Figure 4-12 shows the gas flow through a plate ESP and the discharge and collection plate electrodes. Discharge electrodes are approximately 0.05 to 0.15 inches (0.02 to 0.06 centimeters) in diameter. Collection plates are usually between 20 and 40 feet (6 and 12 meters) high and spaced from 4 to 12 inches (1.6 to 4.7 centimeters) apart.
- Figure 4-13 is a schematic of a single-stage, hot-side plate ESP. The major components are:
  - -- Discharge electrodes (wires) that hang between the collection plate electrodes and that provide the electrical energy required to charge the particles and liquid aerosols in the dirty gas
  - -- Collection electrodes that are placed parallel to each other and collect the charged particulate matter
  - -- High-voltage equipment including a step-up transformer, a high-voltage rectifier, and automatic circuitry that controls the electric field between the discharge and collection electrodes.
  - -- Rappers that remove collected particulate matter that has accumulated on the collection electrodes
  - -- A hopper that is used to store the collected particulate matter temporarily prior to disposal
  - -- A hopper discharge device that removes the collected material from the hopper
  - -- A shell structure that encloses the electrodes and supports the precipitator components in a rigid frame to promote electrode alignment and configuration

HOW DOES AN ESP WORK?

The following steps in sequence describe how an ESP works:

- A high-voltage, pulsating, direct current is applied to the discharge electrodes and the collection electrodes with the discharge electrode being negatively charged and the collection electrode being grounded. The applied voltage creates an electric field and is increased until it produces a Corona discharge, which can be seen as a luminous blue glow around the discharge electrode.
- The dirty exhaust gas enters the ESP such that the gas flows between the collection plate electrodes

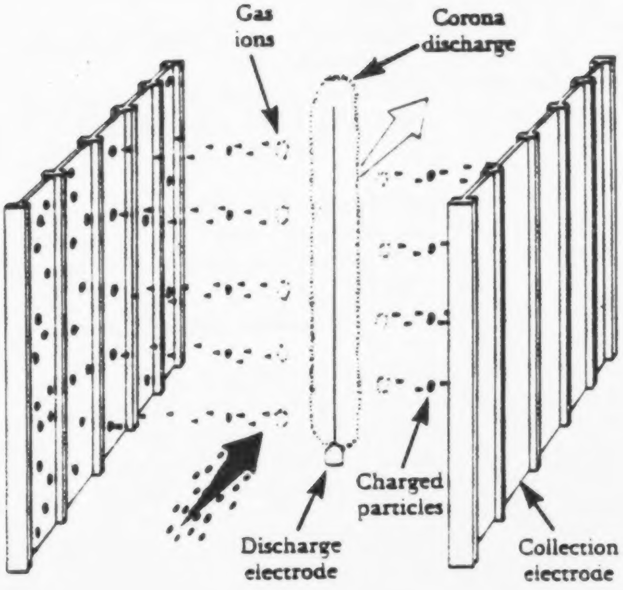
Gas ions
Corona discharge
Charged particles
Discharge electrode
Collection electrode

Figure 4-12. Plate ESP.[7]

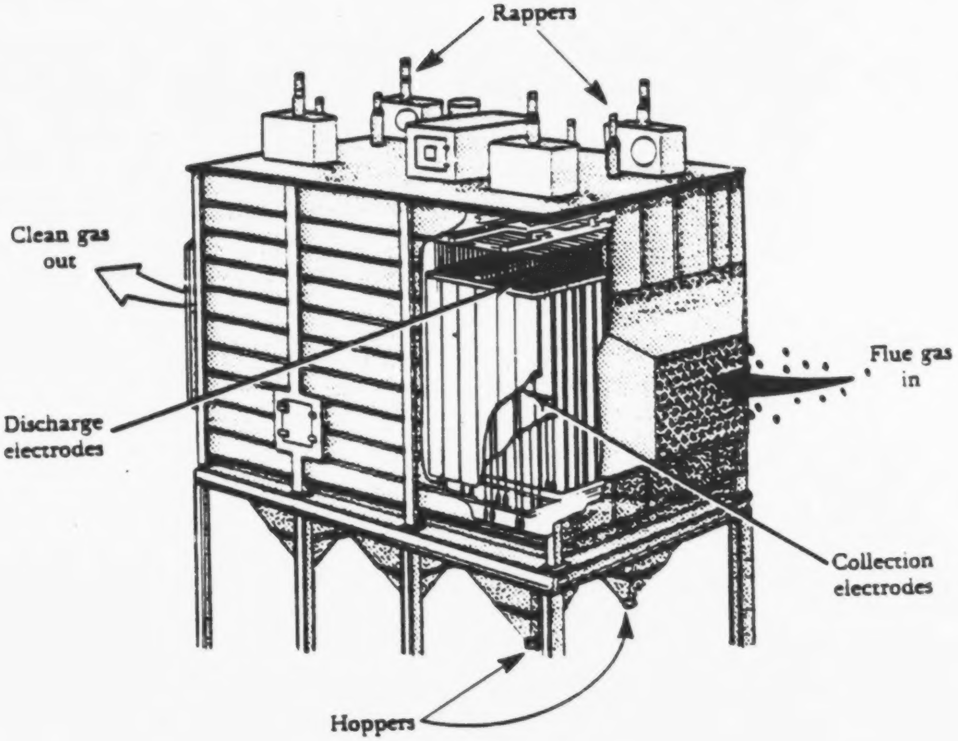
Rappers
Clean gas out
Flue gas in
Discharge electrodes
Collection electrodes
Hoppers

Figure 4-13. Electrostatic Precipitator.[7]

- As the dirty gas comes into contact with the corona, the gas particles become negatively charged.
- The negatively charged particles migrate to the collection electrode because they are repelled from the negatively charged discharge electrodes (like charges) and attracted to the collection electrodes (opposite charges).
- When the charged particles reach the collection plate, the charge on the particle is only partially discharged. The charge is slowly leaked to the grounded collections electrode. A portion of the charge is retained and allows the particle to adhere to the plate and promotes cohesion of other particles to the collected particles on the plate.
- The collection plates are rapped periodically to remove the collected particles. Plates are rapped when the accumulated dust layer is relatively thick (0.03 to 0.5 inches [0.01 to 0.2 centimeters]). This procedure allows large sheets of dust to fall off the plates and helps eliminate dust reentrainment.
- The dislodged dust falls into the hopper where it is removed with a hopper discharge device such as a slide gate or drawer (manual dust removal) or a trickle valve, rotary airlock valve, screw conveyor, or pneumatic conveyor (automatic dust removal).

REVIEW EXERCISE

1. Which of the following types of air pollution control devices are used on hospital incinerators? a. Wet scrubbers b. Fabric filters c. Dry scrubbers d. All of the above	
2. Fine particulate emissions are controlled very effectively by which types of devices? a. Packed-bed scrubbers b. Venturi scrubbers c. Fabric filters d. Dry scrubber systems e. Electrostatic precipitators	1. d. All of the above
3. Pulse-jet fabric filters use a blast of _______ ______ for cleaning the bags	2. b, c, d, and e
4. A dry scrubber is always followed by a high efficiency particulate matter control device. True or False?	3. compressed air
5. Where does acid gas removal from the flue gas occur in a dry injection system? a. Venturi contactor b. Flue gas ductwork c. Fabric filter d. All of the above	4. True
6. Both the spray dryer and dry injection types of dry scrubbers inject dry alkaline sorbent into the flue gas stream. True or False?	5. d. All of the above

(continued)

REVIEW EXERCISE (CONTINUED)

7. A venturi scrubber's control efficiency and operating costs increase with increased gas velocity and pressure drop in the venturi throat. True or False?	6. False. The spray dryer injects liquid slurry.
8. The majority of the fine particulate collected by a fabric filter is filtered out by the _______ ____________.	7. True
	8. filter cake

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7. U. S. Environmental Protection Agency. APTI Course SI:412B, Electrostatic Precipitator Plan Review--Self Instructional Guidebook. EPA 450/2-82-019. July 1983.

8. U. S. Environmental Protection Agency. Operation and Maintenance Manual for Electrostatic Precipitators. EPA/625/1-85/017. September 1985.

SESSION 5.
MONITORING AND AUTOMATIC CONTROL SYSTEMS

SESSION 5. MONITORING AND AUTOMATIC CONTROL SYSTEMS

TABLE OF CONTENTS

Page

SESSION GOAL AND OBJECTIVES.. 5-1

INTRODUCTION.. 5-2

OPERATING PARAMETERS.. 5-7
  Incinerator Operating Parameters.................................... 5-7
  Wet Scrubber Operating Parameters................................... 5-7
  Fabric Filter Operating Parameters.................................. 5-7

TYPES OF AUTOMATIC CONTROL SYSTEMS.................................... 5-7
  Manual Control.. 5-7
  Automatic Timer Sequence.. 5-7
  Automatic Control... 5-11

MONITORING AND CONTROL EQUIPMENT...................................... 5-11
  Temperature... 5-11
  Incinerator Draft and APC Pressure Drop............................. 5-11
  Oxygen Concentration.. 5-12
  Carbon Monoxide Concentration....................................... 5-12
  Opacity... 5-17
  Charging Rate... 5-17
  Scrubber Liquid pH.. 5-17

REFERENCES FOR SESSION 5.. 5-20

LIST OF FIGURES

Figure 5-1. Schematic of a temperature monitoring system......... 5-3

Figure 5-2. Schematic of a temperature control loop.............. 5-4

Figure 5-3. Thermostat with temperature "setpoint"............... 5-5

Figure 5-4. Temperature controller/meter......................... 5-6

Figure 5-5. Barometric damper.................................... 5-13

Figure 5-6. Constant speed fan with damper control............... 5-14

Figure 5-7. Schematic of in situ and extractive monitors......... 5-15

Figure 5-8. Schematic of extractive monitoring system............ 5-16

Figure 5-9. Typical transmissometer installation for measuring opacity.................................. 5-18

LIST OF TABLES

Page

TABLE 5-1 TYPICAL MONITOR AND CONTROL PARAMETERS FOR INCINERATORS.. 5-8

TABLE 5-2. TYPICAL MONITOR AND CONTROL PARAMETERS FOR SCRUBBERS. 5-9

TABLE 5-3. TYPICAL MONITOR AND CONTROL PARAMETERS FOR FABRIC FILTERS.. 5-10

SESSION 5.
MONITORING AND AUTOMATIC CONTROL SYSTEMS

SESSION GOAL AND OBJECTIVES

GOAL

To familiarize you with:

- The difference between a parameter that is monitored and automatically controlled and a parameter that is simply monitored;
- The types of operating parameters that may be controlled or monitored;
- The basic types of automatic control systems used on incinerators; and
- The types of monitors that may be included on your incinerator/air pollution control system.

OBJECTIVES

Upon completing this session, you should be able to:

1. List the operating parameters that may be controlled and/or monitored;
2. Distinguish between a monitored and controlled parameter and a parameter which is only monitored;
3. Identify the instruments used to monitor operating parameters;
4. Explain the basic types of control systems typically used on incinerators; and
5. Identify the monitoring and control systems included on your incinerator/air pollution control system.

INTRODUCTION

The type of control system and the operating parameters that are monitored will be different for each incinerator. In this session, the parameters most likely to be monitored and/or controlled are discussed.

It is important to make a distinction between a parameter that is monitored and a parameter that is monitored and automatically controlled. When a parameter is monitored, it means that information is obtained by a sensing device in the incinerator and the information is transmitted to a receiver such as a display meter or recorder for you to view. However, the information from the sensor does not automatically control any operations. Figure 5-1 is a simplified schematic of a temperature monitoring system.

When a monitored parameter is used for control, the information transmitted from the sensor is used to adjust some function(s) within the incineration system that in turn controls the monitored parameter. The control system includes a controller to send a signal to the operating system which is adjusted. Figure 5-2 is a simplified schematic of a temperature control loop which adjusts the primary chamber combustion air blower and burner operations to control the temperature. Control systems use setpoints for the monitored/controlled parameter (in this case the primary chamber temperature) to determine when action will be initiated for the adjusted parameter (in this case, increasing/decreasing the combustion air and turning on or off the primary burner).

A simple control system which you are all familiar with that uses a setpoint is the household thermostat, as shown in Figure 5-3. The desired temperature of the room is set, and the furnace automatically turns on and off in order to maintain this temperature. A temperature dial is provided so you can monitor the room temperature. An example of a temperature monitor/control display which is used on an incinerator is presented in Figure 5-4. This controller has low and high setpoints. Two pointers are used for setting the high and low setpoints, and the third pointer indicates the actual temperature.

So that you can fully appreciate how your incinerator operates, you should know

- Which parameters are monitored and how the monitored value is displayed; and
- Which of the monitored parameters are automatically controlled, and what incinerator operating functions they adjust.

The next section lists the most frequently monitored/controlled parameters and the operating functions that they may be used to adjust. Each incinerator will use different monitoring and control systems.

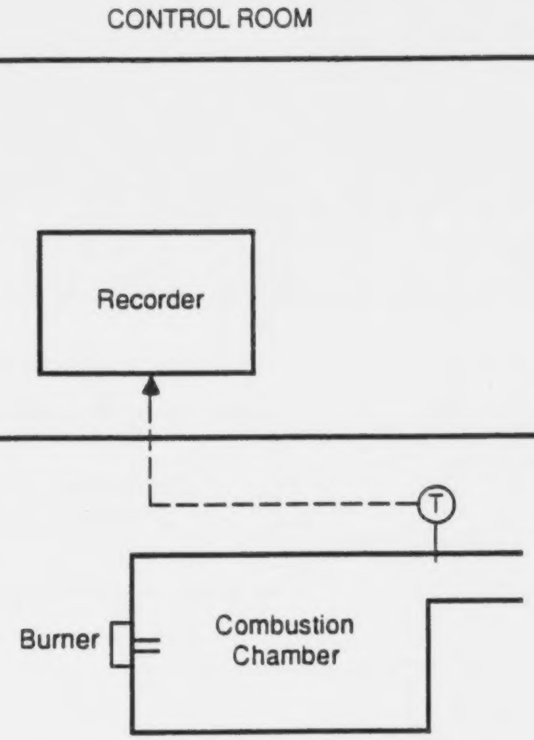
CONTROL ROOM
Recorder
T
Burner
Combustion Chamber

Figure 5-1. Schematic of a temperature monitoring system.

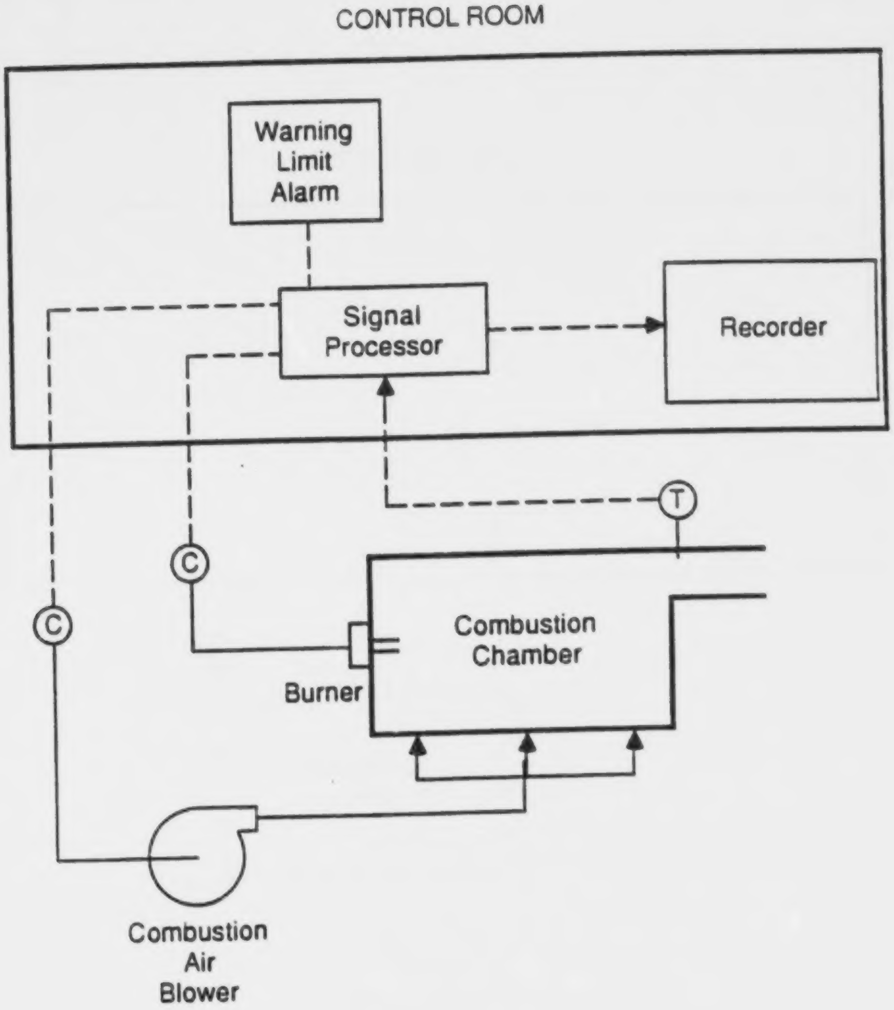
CONTROL ROOM
Warning Limit Alarm
Signal Processor
Recorder
T
C
C
Combustion Chamber
Burner
Combustion Air Blower

Figure 5-2. Schematic of a temperature control loop.

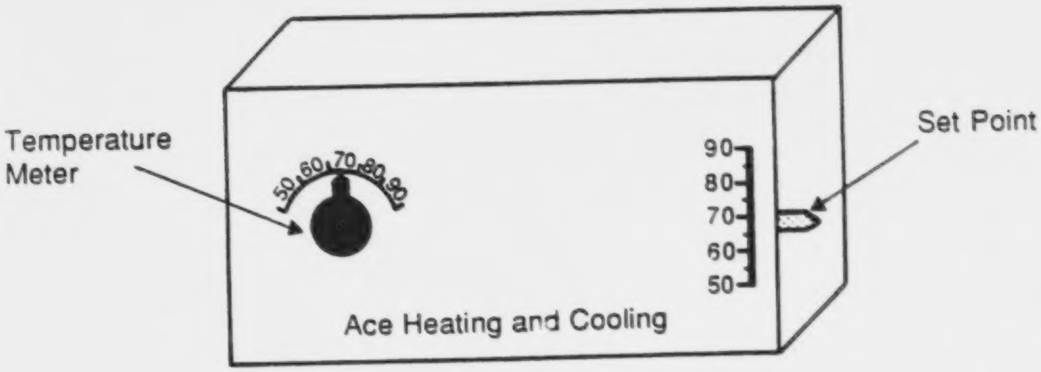
Temperature
Meter
50
60
70
80
90
Set Point
90
80
70
60
50
Ace Heating and Cooling

Figure 5-3. Thermostat with temperature "setpoint."

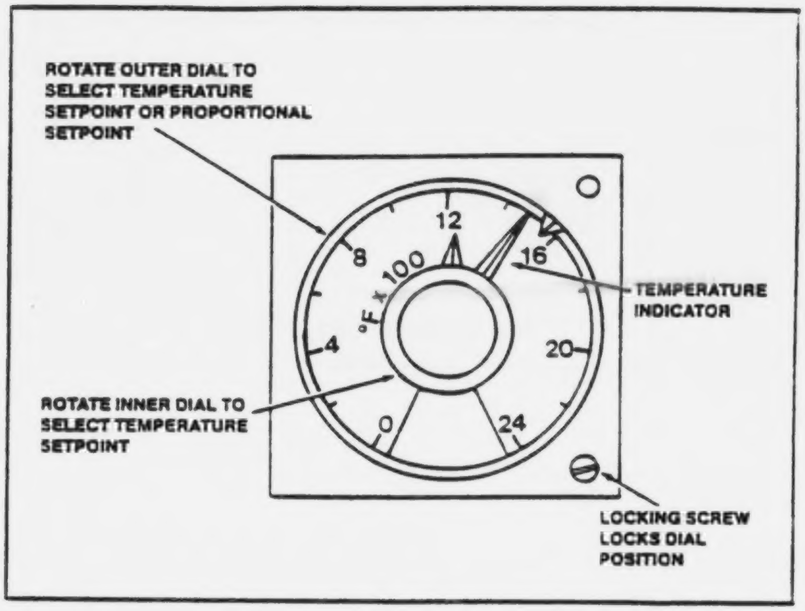
ROTATE OUTER DIAL TO SELECT TEMPERATURE SETPOINT OR PROPORTIONAL SETPOINT
12
8
16
°F x 100
4
20
0
24
TEMPERATURE INDICATOR
ROTATE INNER DIAL TO SELECT TEMPERATURE SETPOINT
LOCKING SCREW LOCKS DIAL POSITION

Figure 5-4. Temperature controller/meter. [1]

OPERATING PARAMETERS

INCINERATOR OPERATING PARAMETERS

The incinerator operating parameters that may be either monitored and/or used as control parameters are listed in Table 5-1. The functions which are typically adjusted when the parameters are used as a control function also are listed in Table 5-1. Temperature is almost always monitored. Typically, the other parameters are monitored only on larger incinerators or if regulatory agencies require that specific parameters be measured, e.g., opacity.

WET SCRUBBER OPERATING PARAMETERS

The wet scrubber operating parameters that may be either monitored and/or used as control parameters are listed in Table 5-2.

FABRIC FILTER OPERATING PARAMETERS

The fabric filter operating parameters that may be monitored and/or used as control parameters are listed in Table 5-3, along with the operating functions which might be adjusted.

TYPES OF INCINERATOR AUTOMATIC CONTROL SYSTEMS

The control systems used for incinerators vary from manually controlled units to highly sophisticated electronically controlled units. Three basic levels of control systems are briefly described below, as an introduction to the typical control systems used on hospital waste incinerators.

MANUAL CONTROL

With a totally manual control system, you make all adjustments including turning burners on or off, adjusting combustion air dampers, and adjusting stack dampers. The on/off cycling of auxiliary burners to control combustion chamber temperatures between low and high setpoints is a simple automatic control which is a step up from full manual control. Also, the use of a barometric damper will automatically control incinerator draft.

AUTOMATIC TIMER SEQUENCE

A preset timer sequence may be used for controlling an incinerator. With this type control system, a time sequence is activated when the incinerator is turned on. The time sequence controls combustion air and burner operations in conjunction with temperature setpoints. In a typical timer control sequence, forced draft combustion blower settings (either on/off or low/high) are activated based on the preset time sequence. For example, the primary combustion air blower may start off in the "low" air setting and continue to supply air at a low rate until 1 hour into the cycle; at this time, the control time causes the blower to shift to the "high" combustion air rate.

TABLE 5-1. TYPICAL MONITOR AND CONTROL PARAMETERS FOR INCINERATORS.

Monitored/controlled parameter	Purpose	Incinerator functions controlled (when applicable)
Temperature (primary and secondary chambers)	Indicates temperature operating range; Control parameter	Combustion air Auxiliary burners
Draft	Indicates pressure in chamber; Control parameter	Barometric damper ID fan damper
Oxygen	Indicates excess air level	Combustion air
Carbon monoxide	Indicator of combustion efficiency	--
Opacity	Indicator of emissions	--
Charge rate	Records charge rate	Automatic feed system interlock

TABLE 5-2. TYPICAL MONITOR AND CONTROL PARAMETERS FOR SCRUBBERS.

Monitored parameter	Scrubber functions controlled (when applicable)
Pressure and pressure drop	Venturi throat ID fan
Scrubber liquid flow rate or pressure	Liquid flow control valve
Scrubber liquid pH	Caustic flow control valve
Inlet temperature	Emergency quench/dilution air Bypass stack Prequench

TABLE 5-3. TYPICAL MONITOR AND CONTROL PARAMETERS FOR FABRIC FILTERS

Monitored parameter	Fabric filter operating functions controlled
Pressure drop	Cleaning cycle
Inlet gas temperature	Emergency bypass stack

The auxiliary burners also are turned on/off or shifted from low to high fire rates based on the timer sequence. Low and high temperature setpoints are provided to override the time control sequence if the low/high temperature setpoints are exceeded; that is, if the high temperature setpoint is exceeded, the burner will cycle back to low fire even though the burner would normally be operating at a high fire based on the time sequence.

AUTOMATIC CONTROL

With a typical fully automatic control system, the combustion air level is automatically adjusted over a full operating range (rather than just high/low settings). The system adjusts the combustion air based on input from temperature and/or oxygen monitors. The burners are cycled on or off if preset low and high temperature setpoints are reached. The incinerator draft is automatically controlled by a barometric damper or control dampers on the induced draft fan.

MONITORING AND CONTROL EQUIPMENT

The following sections describe the types of instrumentation used to monitor or control the operating parameters described previously.

TEMPERATURE

Thermocouples are used to monitor temperatures in the incinerator's combustion chambers and inlet gas to the air pollution control system. The thermocouples usually are located near the exit of each combustion chamber and upstream of the air pollution control device. The temperature readout may be a strip or circular recorder, a digital display, or a temperature gauge. The chart recorder provides a permanent record of the temperatures experienced by the thermocouples. Thermocouples usually are very reliable instruments. However, to avoid operational problems, regular replacement of thermocouples is recommended. Some incinerators may employ dual thermocouples in order to detect thermocouple malfunctions. These malfunctions should be reported to the maintenance department.

Most incinerators are equipped so that the minimum temperatures required by regulations or recommended by manufacturers are maintained. These minimum temperatures are maintained through the use of temperature setpoints. Once the temperature measured by the thermocouple drops below the temperature setpoint. then the temperature is increased by either burning auxiliary fuel or by adjusting the combustion air supply or both.

INCINERATOR DRAFT AND APC PRESSURE DROP

Pressure drop is measured with a differential pressure gauge. To monitor incinerator draft, one side (high-pressure side) of this instrument is always open to the ambient air while the other side (low-pressure side) is connected by tubing or piping to the incinerator chamber. Incinerator draft can be automatically controlled using a barometric damper for natural draft systems. Figure 5-5 is a schematic of a barometric damper. The damper automatically opens and closes (via a mechanical system) to maintain a constant pressure differential between the incinerator chamber and the atmosphere, as measured by the draft monitor. For induced draft systems, the draft typically is controlled by opening and closing a damper located before or after the induced draft fan. Figure 5-6 shows a damper control system for an induced draft fan. Airflow is decreased as the damper is closed, as depicted in the figure. The damper can be adjusted manually or can be automatically adjusted by a mechanical system based upon the output from the draft monitor.

To monitor the pressure drop across an APC device, a differential pressure gauge also is used. The high-pressure side of the gauge is connected upstream of the control device and the low-pressure side is connected downstream of the control device to measure the pressure drop across the APC.

OXYGEN CONCENTRATION

Some incinerators may be equipped with oxygen monitors. The oxygen sensor typically is located in the duct to the stack or in a duct at the exit of the secondary combustion chamber. These monitors analyze the oxygen concentration in the combustion gases from the secondary combustion chamber so that the operator can ensure that enough oxygen is available for proper combustion. For some incinerators with oxygen analyzers, the oxygen levels measured are used to automatically control the combustion air feed rates to the incinerator.

The two main designs used for oxygen analyzers are in situ and extractive analyzers. Figure 5-7 depicts the in situ and extractive designs. In situ oxygen analyzers provide rapid response to changes in the oxygen content of the gas because the sensor is actually mounted in direct contact with the gas stream. The extractive technique involves the continuous withdrawal of a sample of gas that is transported via a sample line to the analyzer which is located some distance from the sampling point. Figure 5-8 is a schematic of an example extractive analyzer system showing the gas conditioning and calibration components of the system.

CARBON MONOXIDE CONCENTRATION

Some incinerators may be equipped with carbon monoxide (CO) monitors. These monitors analyze the CO concentration in the combustion gases from the secondary combustion chamber to ensure that proper combustion conditions are maintained and CO emissions are minimized. In general, high CO levels indicate that incomplete combustion is occurring. Typically, CO monitors are not part of the automatic process control system.

As with oxygen analyzers, CO analyzers usually are located at the secondary combustion chamber exit or in the stack breaching and may be either in situ or extractive. However, CO analyzers are usually

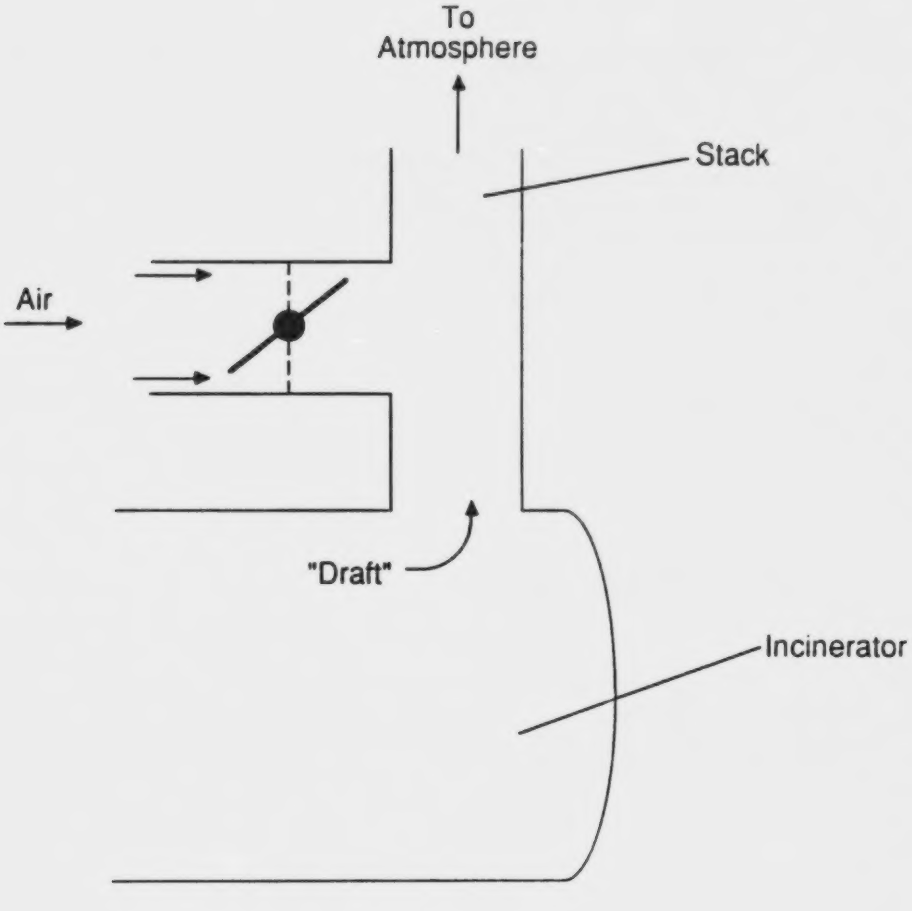
To Atmosphere
Stack
Air
"Draft"
Incinerator

Figure 5-5. Barometric damper.

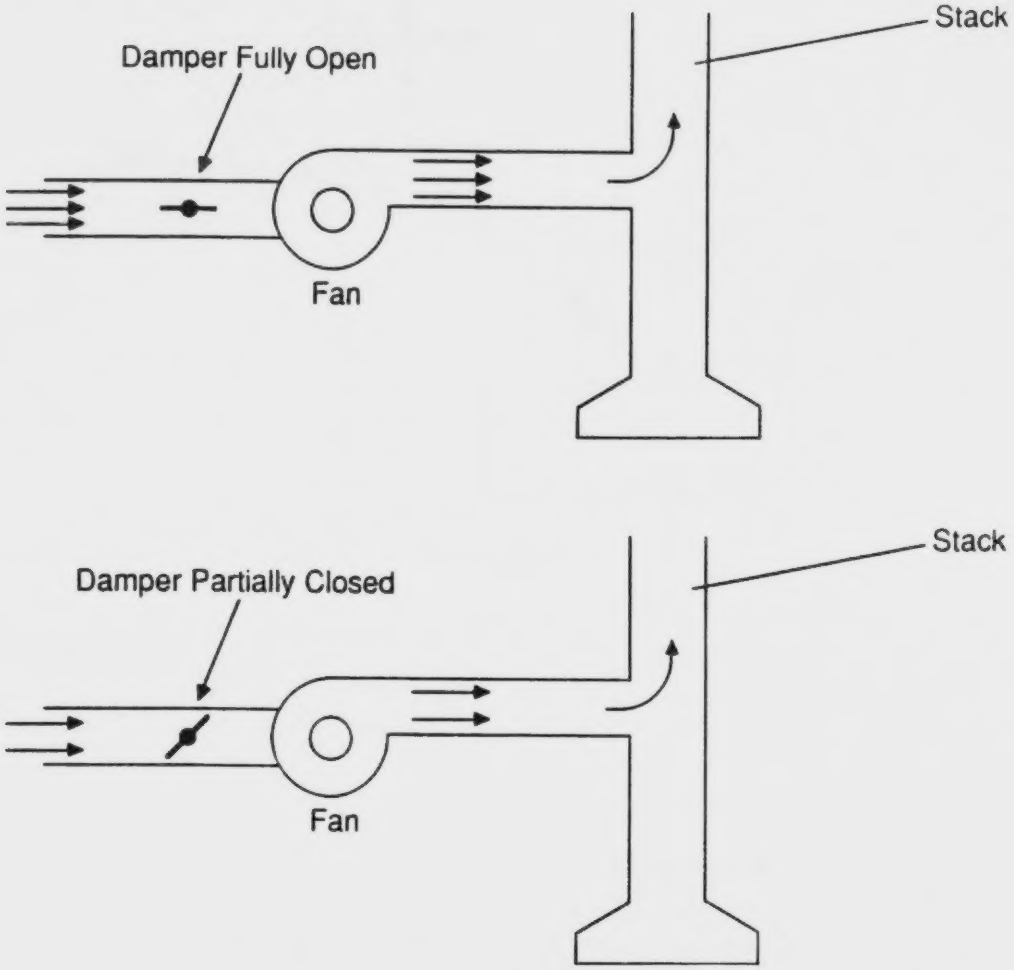
Stack
Damper Fully Open
Fan
Stack
Damper Partially Closed
Fan

Figure 5-6. Constant speed fan with damper control.

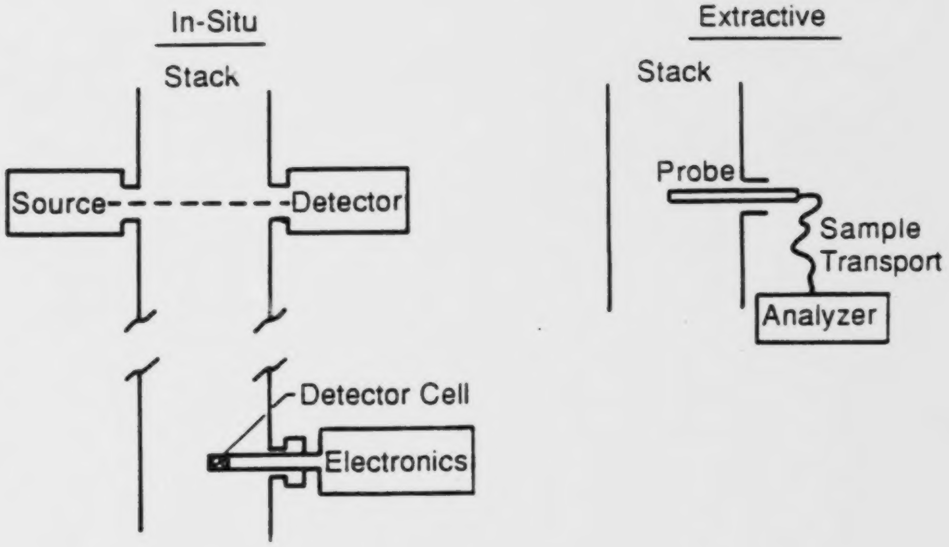
In-Situ
Stack
Source
Detector
Detector Cell
Electronics
Extractive
Stack
Probe
Sample Transport
Analyzer

Figure 5-7. Schematic of in situ and extractive monitors.

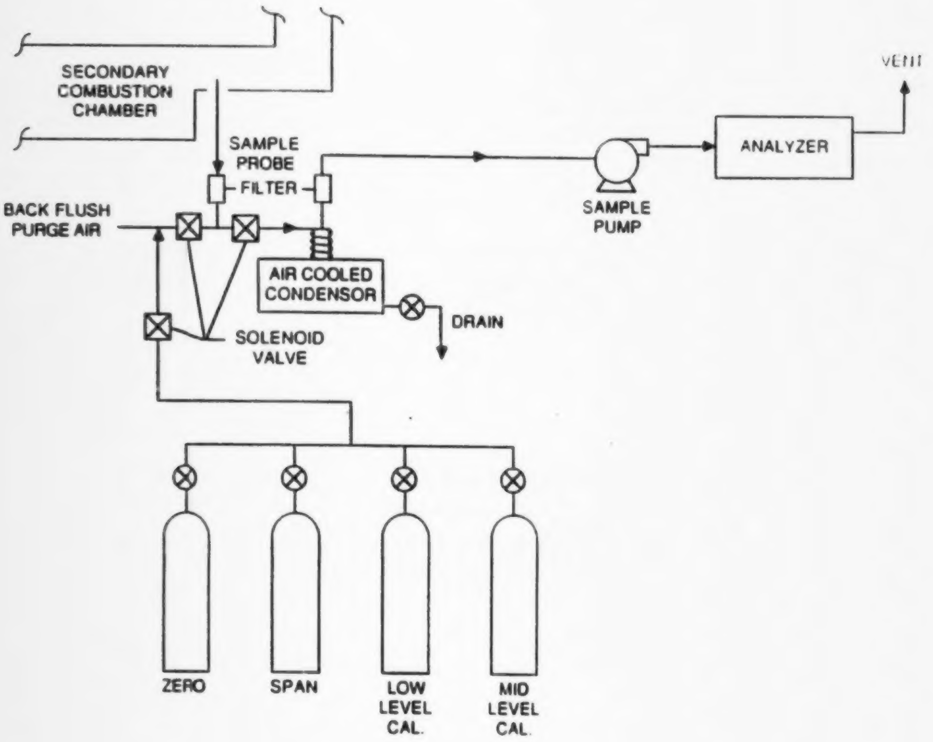
SECONDARY
COMBUSTION
CHAMBER
SAMPLE
PROBE
FILTER
BACK FLUSH
PURGE AIR
AIR COOLED
CONDENSOR
SOLENOID
VALVE
DRAIN
SAMPLE
PUMP
ANALYZER
VENT
ZERO
SPAN
LOW
LEVEL
CAL.
MID
LEVEL
CAL.

Figure 5-8. Schematic of extractive monitoring system.

extractive because water vapor in the exhaust gas interferes with the CO analysis and, therefore, must be removed through gas conditioning steps associated with the extractive analyzer. Problems with CO analyzers are usually associated with pluggage in the system or small air in-leaks that distort the readings.

OPACITY

Opacity monitors (transmissometers) are used as indicators of proper operation rather than as part of the automatic control system. Opacity monitors are almost always located in the stack or stack breeching and measure the amount of light absorbed by the stack plume from a light source directed across the stack. Figure 5-9 is a schematic of transmissometer installation. A transmissometer cannot be used after a wet scrubber because the gas stream contains so much moisture that a visible plume caused by the moisture interferes with the opacity measurement.

CHARGING RATE

Waste charging rate can be monitored manually or automatically. Manual monitoring involves weighing each load of waste and recording the weight of the charge. Automatic monitoring involves use of a weigh scale or weigh hopper that automatically records the weight of each charge placed on the scale or in the hopper.

SCRUBBER LIQUID pH

As the acid gases are scrubbed from the exhaust gas, the scrubber liquor pH will become acidic. Caustic solution can be added to the scrubber liquor to neutralize the solution. The pH is monitored using a pH electrode. The electrode is placed into a sump or a pipe through which the scrubber liquor flows. The output from the pH meter can be used to control the pH of the scrubber liquor automatically by operating a valve which controls the flow of caustic solution to the scrubber liquor.

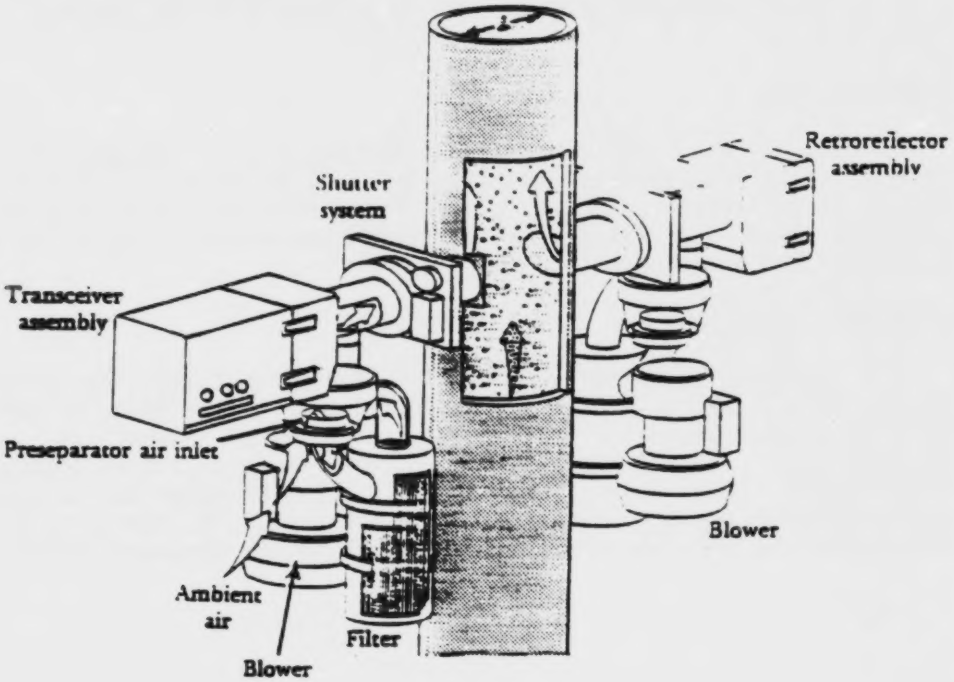
Retroreflector assembly
Shutter system
Transceiver assembly
Preseparator air inlet
Blower
Ambient air
Filter
Blower

Figure 5-9. Typical transmissometer installation for measuring opacity.[2]

REVIEW EXERCISE

1. List five incinerator operating parameters that may be either controlled or monitored.

2. List three wet scrubber operating parameters that may be either controlled or monitored.

3. When a control parameter such as temperature is used to adjust an operating function (such as an auxiliary burner), _______ often are used to determine when the function is activated.

4. Thermocouples are used to monitor ______.

5. Thermocouples usually are located at the _______ of each combustion chamber and upstream of the air pollution control device.

6. Pressure drop is usually measured with a _____ ________ gauge.

7. Oxygen monitors usually are located at the exit to the ______ combustion chamber or in the ductwork of the ________.

8. The two basic types of oxygen and CO monitors used are called in situ and __________.

9. Typically, CO monitors are part of the automatic process control system. True or False?

10. Opacity monitors are used as indicators of proper operation and are not part of the automatic control system. True or False?

1. Temperature, draft, oxygen concentration, carbon monoxide concentration, opacity, charge rate

2. Pressure and pressure drop, scrubber liquid flow rate, scrubber liquid pH, temperature of inlet gas

5. setpoints

4. temperature

5. exit

6. differential pressure

7. secondary, stack

8. extractive

9. False

10. True

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SESSION 6.
INCINERATOR OPERATION

SESSION 6. INCINERATOR OPERATION

TABLE OF CONTENTS

Page

SESSION GOAL AND OBJECTIVES.. 6-1

INTRODUCTION... 6-1

WASTE HANDLING... 6-2
  Sturdy Containers.. 6-2
  Minimizing Waste Handling.. 6-3
  Proper Operation of Waste Charging System........................ 6-3
  Secure Storage... 6-3
  Do's and Don'ts of Waste Handling................................ 6-3

KEY OPERATING PARAMETERS... 6-4
  Key Operating Parameters for Controlled-Air Incinerators........ 6-4
  Key Operating Parameters for Multiple-Chamber Incinerators...... 6-8

OPERATION OF CONTROLLED-AIR INCINERATORS........................... 6-10
  Proper Waste Charging Procedures................................. 6-10
  Controlling and Monitoring Key Operating Parameters............. 6-12
  Other Parameters to Monitor...................................... 6-18
  Summary of Control and Monitoring Techniques for Controlled-Air Incinerators.................................... 6-19
  Proper Ash Handling Procedures................................... 6-23
  Startup and Shutdown Procedures.................................. 6-24
  Do's and Don'ts for Operating a Controlled-Air Incinerator...... 6-25

OPERATION OF MULTIPLE-CHAMBER INCINERATORS......................... 6-26
  Introduction... 6-26
  Proper Waste Charging Procedures................................. 6-26
  Controlling and Monitoring Key Operating Parameters............. 6-30
  Summary of Control and Monitoring Techniques for Multiple-Chamber Incinerators.. 6-34
  Proper Ash Handling Procedures................................... 6-34
  Startup and Shutdown Procedures.................................. 6-35
  Do's and Don'ts for Operating a Multiple-Chamber Incinerator.... 6-36

REFERENCES FOR SESSION 6... 6-40

LIST OF FIGURES

Page

Figure 6-1. Example combustion chamber temperature trends--moderate volatile content waste.................... 6-15

Figure 6-2a. Proper and improper burner flame patterns........... 6-20

Figure 6-2b. Proper and improper burner flame patterns........... 6-21

Figure 6-2c. Proper and improper burner flame patterns........... 6-22

Figure 6-3. Improper charge procedures: stuffing and burning... 6-28

Figure 6-4. Proper and improper charging: waste bed distribution.. 6-29

LIST OF TABLES

TABLE 6-1. KEY INCINERATOR OPERATING PARAMETERS AND RECOMMENDED OPERATING RANGE: CONTROLLED-AIR INCINERATOR........ 6-5

TABLE 6-2. KEY INCINERATOR OPERATING PARAMETERS AND RECOMMENDED OPERATING RANGE: MULTIPLE-CHAMBER INCINERATOR...... 6-9

SESSION 6.
INCINERATOR OPERATION

SESSION GOAL AND OBJECTIVES

GOAL

To familiarize you with:

- Proper waste handling procedures;
- Proper waste charging procedures;
- Key operating parameters for the incinerator and how they can be monitored and controlled;
- Proper ash removal and handling procedures; and
- Special actions required and possible problems with startup and shutdown of the incinerator.

OBJECTIVES

Upon completing this session, you should be able to:

1. Recognize the do's and don'ts of waste handling and charging;
2. Identify the key operating parameters for multiple-chamber and controlled-air incinerators;
3. State the operating range that is considered acceptable for each key operating parameter;
4. Describe how to monitor each key operating parameter;
5. List the special actions required for startup and shutdown of the incinerator; and
6. Recognize the do's and don'ts of ash removal and handling.

INTRODUCTION

Many types of incinerators are used for the incineration of medical wastes. The capacity of the incinerators varies tremendously because each incinerator model is designed differently; design criteria, operating parameters, and operating procedures will vary. The type of control system and the degree of automatic control and monitoring used with a specific incinerator also will vary.

As a result, this course cannot instruct you on how to operate your specific incinerator and is not intended to do so. Specific onsite training from the manufacturer of your incinerator, or a qualified consultant, is recommended. The objective of this session is to provide you with a basic understanding of the most important operating parameters and how you can monitor and control them. With a basic understanding of the key parameters, you should be able to better understand the operation of your system.

The operator is in control of many of the factors that have an impact on the performance of the incinerator including:

- Startup and shutdown;
- Waste charging procedures;
- Monitoring and adjusting operating parameters; and
- Ash handling.

The primary concern is to assure that the incinerator is operated in a manner so that:

- Infectious materials in the waste are rendered harmless; and
- Air pollution emissions are minimized.

In this session we will:

- Discuss proper waste handling procedures;
- Identify key operating parameters;
- Identify recommended operating ranges for the key parameters;
- Discuss operation of controlled-air incinerators; and
- Discuss operation of multiple-chamber incinerators.

WASTE HANDLING

Typically, you will be responsible for handling the waste prior to charging it to the incinerator. The primary concern with infectious waste handling is to avoid exposure of yourself and others to pathogens and avoid injury from sharp objects such as needles and broken glass. Proper procedures dictate that:

- Sturdy containers (including bags) are used;
- Waste handling is minimized;
- Mechanical waste charging devices are properly operated and maintained; and
- The waste storage area is secure and away from public traffic.

STURDY CONTAINERS

As an operator, you probably do not have control over the type of waste containers that are used. However, if breakage and spillage is a problem, you have an obligation to notify hospital management. Several things can be done if bag breakage is a problem. These include:

- Using stronger bags;
- Double bagging;
- Loading less material into each bag;
- Placing the bags in rigid containers such as cardboard boxes or barrels which can be incinerated.

MINIMIZING WASTE HANDLING

As an operator, you have some control over the handling of the waste. The less you handle the waste the less chance there is of breaking bags or injuring yourself. You should think of ways you can minimize handling of the waste.

One example of how waste handling can be minimized is the use of rolling carts to transport and store the waste before charging. Once the red bags are placed in the carts and transported to the incinerator, the bags should not need to be handled again until the bags are loaded directly from the cart into the incinerator charging system. It does not make sense to unload the bags from the cart and pile them on the ground and then have to pick them up again to load them into the incinerator.

PROPER OPERATION OF WASTE CHARGING SYSTEM

To minimize breaking and spilling bags, the mechanical charging system should be properly operated.

Hopper/Ram Systems. Do not overfill the hopper by jamming waste into it. Do not force the hopper door closed.
Automatic Cart Dump Systems. Do not overfill the carts.

SECURE STORAGE

The waste should be stored in a safe and secure way--even if stored only for a short period of time. The following are guidelines:

- The waste storage area should be out of the way of normal hospital pedestrian traffic.
- The area should be secure from public access.
- The storage area or containers should be secure from rodents which can contract and transmit disease.

An example of poor waste storage is throwing the bags in a pile on the loading dock adjacent to the hospital parking lot. An example of better waste storage is to leave the bags in transport carts inside an area protected by a chainlink fence and with limited access. An example of even better waste storage is to leave the bags in transport carts inside a well ventilated building which houses the incinerator charging system. Some State regulations require that infectious wastes be stored under refrigeration if they are not to be incinerated within a specified time period (e.g., 24 hours).

DO'S AND DON'TS OF WASTE HANDLING

DO:

- Minimize your handling of the waste.
- Report repeated problems with bag breakage/spillage to hospital administrators.

- Assure that the waste to be charged is safely stored if it will not be immediately charged.

DON'T:

- Throw bags around and cause the bags to break and spill.
- Misuse mechanical charging systems and cause the bags to break and spill.

KEY OPERATING PARAMETERS

In this section, the key operating parameters for controlled-air and multiple-chamber incinerators are identified, and operating ranges consistent with "good operating practice" for the key parameters are presented. The rationales for the operating ranges also are presented. However, incinerator designs differ, and operation of a particular incinerator outside the recommended ranges may be appropriate. The objective is to operate the incinerator in such a manner to achieve complete combustion, sterilize the ash, and minimize air pollutants. Furthermore, in many cases, specific operating limits are established by regulatory agencies; these limits may differ from the recommended operating ranges presented here. Obviously, the incinerator should be operated within the regulatory limits.

First, the key operating parameters for controlled-air incinerators are presented and discussed. Then the operating parameters for multiple-chamber incinerators are presented and discussed.

KEY OPERATING PARAMETERS FOR CONTROLLED-AIR INCINERATORS

Table 6-1 summarizes the key operating parameters and recommended operating ranges for the typical controlled-air incinerator.

The key operating parameters are:

- Primary chamber temperature;
- Secondary chamber temperature;
- Charging rate;
- Primary chamber combustion air level;
- Total combustion air level;
- Combustion gas oxygen concentration; and
- Primary combustion chamber draft.

Each of these parameters is briefly discussed below.

Primary and Secondary Combustion Chamber Temperatures. The key parameter most likely to be monitored by the operator is the temperature of both chambers. The temperature ranges for the two chambers are different because the functions of the two chambers are different.

Both upper and lower limits on the temperature range for each chamber are necessary.

TABLE 6-1. KEY INCINERATOR OPERATING PARAMETERS AND RECOMMENDED OPERATING RANGE: CONTROLLED-AIR INCINERATOR

Parameter	Incinerator type		
	Batch feed	Intermittent feed	Continuous duty
Primary chamber temperature, °F	1000° to 1800°	1000° to 1800°	1000° to 1800°
Combustion (secondary) chamber temperature, °F	1800° to 2200°	1800° to 2200°	1800° to 2200°
Charging rate, lb/h	Fill chamber once at beginning of cycle	10 to 25 percent of rated capacity at 5 to 15 min intervals	10 to 25 percent of rated capacity at 5 to 15 min intervals
Primary chamber combustion air (percent of stoichiometric)	30 to 80	30 to 80	30 to 80
Total combustion air (percent excess air)	140 to 200	140 to 200	140 to 200
Combustion gas oxygen concentration, percent	12 to 14	12 to 14	12 to 14
Primary chamber draft, in w.c.	-0.05 to -0.1	-0.05 to -0.1	-0.05 to -0.1
Burndown period, h	2 to 5	2 to 5	Not applicable

- The temperature is maintained above the lower limit to assure complete combustion of organic compounds and destruction of pathogens.
- The temperature is maintained below the upper limit to prevent damage to the incinerator refractory and slagging of the ash.

The recommended operating ranges which are considered to be good operating practice are as follows:

- Primary chamber lower limit: Greater than 1000°F (540°C).

The chamber must be maintained at a temperature sufficient to maintain combustion, combust the fixed carbon in the waste, and sterilize the remaining ash. For continuous-duty, controlled-air incinerators, a minimum temperature of 1000°F (540°C) also is recommended. However, a higher temperature such as 1400°F (760°C) may be needed to assure combustion of the fixed carbon since the retention time of the ash in the incinerator may be less than for batch and intermittent-duty incinerators. The temperature necessary to achieve an acceptable ash burnout quality should be used.

- Primary chamber upper limit: less than 1800°F (980°C).

The primary chamber must be maintained below a temperature where slagging of the waste occurs and damage to the refractory may occur.

It should be cautioned that a higher primary chamber temperature is not necessarily always better (e.g., 1700°F is not necessarily better than 1200°F). Many factors must be considered, including waste characteristics. One manufacturer reports that based on their experience, the volatilization rate of plastics can be significantly affected by the temperature in the primary chamber (i.e., more rapid volatilization at 1800°F than 1100°F). Based on their experience, operating the primary chamber at the lower end of the recommended range helps to minimize rapid increases in flue gas volume when highly volatile wastes are charged and results in improved operation because the secondary chamber is not overloaded with volatile gases.

- Secondary chamber lower limit: greater than 1800°F (980°C).

The temperature of the secondary chamber must be maintained at a high enough level to assure complete combustion of all organic compounds. The exact temperature required for this is dependent upon many things, including the compound, the oxygen level, how well the gases are mixed with the oxygen, and how long they are in the combustion chamber. A lower limit of 1800°F is recommended.

- Secondary chamber upper limit: less than 2200°F (1200°C).

The temperature of the secondary chamber must be maintained below a level which causes damage to the refractory; this level usually is around 2200°F (1200°C) for sustained operation, but is dependent on the type refractory used.

NOTE: Many regulatory agencies have established specific lower temperature limits for each combustion chamber. These limits may differ from the recommended limits presented in Table 6-1. Therefore, if your permit establishes a lower level temperature limit, you must operate above this limit.

Typical regulatory limits are:

1. Primary chamber temperature--must operate at greater than 1400°F (760°)
2. Secondary chamber temperature--must operate at greater than 1600°F (870°C)

Charging Rate. Each incinerator is designed for a specific heat input rate. The heat input comes from the waste, and as necessary, auxiliary fuel burner(s). Under ideal conditions, an incinerator operates under "steady state", that is with a constant, steady heat input.

For controlled-air incinerators, the heat release from the waste is controlled, within a range, by controlling the combustion air to the primary chamber. In a sense, the fundamental control of the heat release in an incinerator is obtained by controlling the quantity and frequency of waste charges, especially if the waste contains a significant quantity of volatile compounds.

Steady state operating conditions are approached as:

- The waste composition (heat content, moisture, volatiles) becomes more consistent;
- The charge loads decrease in size; and
- The charges are made more frequently.

Therefore, frequent charges of smaller volume may be more desirable than one large charge.

Because waste feed charging procedures are so important and because they can be controlled by the operator, proper charging procedures are discussed separately in the next section.

Primary and Secondary Combustion Air Level and Combustion Gas Oxygen Concentration. The primary chamber air is maintained below the stoichiometric level in controlled-air incinerators. Excess air is supplied to the secondary chamber. The total combustion air level typically is 140 to 200 percent excess air. Excess air is necessary to help assure that sufficient oxygen is available for complete combustion.

The oxygen level in the stack gas is an indicator of the excess air level. An oxygen concentration of 12 to 14 percent roughly coincides with 140 to 200 percent excess air.

Combustion Chamber Draft. A negative combustion chamber pressure typically is maintained. Excessive negative pressure is not desirable because it can cause fine particulate matter to be pulled from the primary chamber through the secondary chamber and out the stack. Also, excessive negative pressure can cause excessive air infiltration through leaks into the incinerator. A typical range for the draft in the primary chamber is -0.05 to -0.10 inch of water column (in. w.c.) (-0.012 to -0.025 kilopascals [kPa]).

KEY OPERATING PARAMETERS FOR MULTIPLE-CHAMBER INCINERATORS

Table 6-2 summarizes the key operating parameters for the typical multiple-chamber incinerator.

The key operating parameters are:

- Primary chamber temperature;
- Secondary chamber temperature;
- Charging rate;
- Ignition chamber combustion air level (percent excess air);
- Total combustion air level (percent excess air);
- Combustion gas oxygen concentration; and
- Primary and secondary combustion chamber pressure.

Each of these parameters is briefly discussed below. Many of these operating parameters have already been discussed in detail for controlled-air incinerators. Therefore, the discussion is abbreviated here.

Primary And Secondary Combustion Chamber Temperature.

The key parameter most likely to be monitored by the operator of a multiple-chamber incinerator is the temperature of each chamber. The temperature is maintained above the recommended lower limit to assure complete combustion of organic compounds and sterilization of the ash. The temperature is maintained below the upper limit to prevent waste slagging and damage to the incinerator refractory. The recommended ranges are:

- Primary chamber--1000° to 1400°F (540° to 760°C)
- Secondary chamber--1800° to 2200°F (980° to 1200°C)

As noted in Table 6-2, a higher temperature is recommended in the primary chamber when incinerating pathological wastes. The higher temperature is recommended to facilitate the burndown of the waste.

Many regulatory agencies have established lower limits for each combustion chamber. If your operating permit establishes a lower temperature limit, you must operate the incinerator above this limit.

Charging Rate. The charging rate and procedures used are very important for operation of a multiple-chamber incinerator.

Note that charging rates for general refuse/red bag and pathological wastes are presented differently in Table 6-2 because of their different waste characteristics. For general refuse/red bag waste, it is important to make frequent, small charges to avoid large surges of volatile

TABLE 6-2. KEY INCINERATOR OPERATING PARAMETERS AND RECOMMENDED OPERATING RANGE: MULTIPLE-CHAMBER INCINERATOR

Parameter	Pathological waste	General refuse
Ignition chamber temperature, °F	1600 to 1800	1000 to 1400
Combustion (secondary) chamber temperature, °F	1800 to 2200	1800 to 2200
Charging rate	Single layer on hearth	10 to 25% of rated capacity at 5- to 15-min intervals
Ignition chamber combustion air (percent excess air)	80	150
Total combustion air (percent excess air)	120 to 200	250 to 300
Combustion gas oxygen concentration, percent	10 to 14	15 to 16
Ignition chamber draft, in. w.c.	-0.05 to -0.1	-0.05 to -0.1

combustible gases that can exceed the capacity of the combustion air supplied in the primary and secondary chambers. Pathological waste must be exposed to a direct flame to achieve combustion.

Primary And Secondary Chamber Combustion Air Levels And Combustion Gas Oxygen Concentration. The primary chamber for a multiple-chamber incinerator is typically maintained at an excess air level of about 200 percent. A multiple-chamber incinerator is operated at an overall excess air level of about 250 to 300 percent. This results in combustion gas oxygen levels in the 15 to 16 percent range. Multiple-chamber incinerators burning pathological wastes typically are operated at lower excess air levels than incinerators burning general refuse. Less excess air is used because pathological waste contains less volatiles and the heat input comes primarily from auxiliary burners.

Primary Chamber Draft. A negative pressure must be maintained in the combustion chambers. Sufficient draft must be maintained to move the combustion gases through the incinerator. Too much draft will cause excessive entrainment of particulate matter from the primary chamber, which will be emitted as an air pollutant. Excessive draft also will increase the air in-leakage to the incinerator which increases the excess air level. The typical range for the primary chamber draft is -0.05 to -0.10 in. w.c. (-0.012 to -0.025 kPa).

OPERATION OF CONTROLLED-AIR INCINERATORS

This section discusses the operation of controlled-air incinerators, including:

- Proper waste charging;
- How to monitor and control the key operating parameters;
- Proper ash handling; and
- Starting up and shutting down the incinerator.

PROPER WASTE CHARGING PROCEDURES

Proper waste charging is probably the most important procedure for the operator. Remember that the heat input rate to an incinerator is very important because the incinerator is sized for a particular heat release rate:

- If the release rate is too low, the incinerator will not operate efficiently and excessive auxiliary fuel will be required.
- If the heat release rate is too high, incomplete combustion is likely to occur causing pollution.

As an operator, you should be aware that the heat content of wastes may vary and therefore you may need to vary the charging procedures--that is, you may need to charge more or less waste.

Special care should be taken to avoid overcharging the incinerator (beyond its intended use) with pathological wastes (animal carcasses and body parts) because of the high moisture content and low heat value of this type waste. (Incineration of large quantities of these wastes is discussed later).

In Session 3, the operating mode of controlled-air incinerators was described as:

- Single batch;
- Intermittent duty; or
- Continuous duty.

The charging procedures used for these three operating modes are slightly different and are discussed separately below.

Single-Batch Incinerators. The following general principles apply for charging single batch incinerators.

- These incinerators are usually small and, therefore, are charged manually.
- The incinerator is charged cold.
- The waste is loaded into the ignition chamber, which is filled to the capacity recommended by the manufacturer.
- The incinerator chamber should not be overstuffed. Overstuffing can result in blockage of the air port to the combustion chamber. Overstuffing also can result in damage to the primary burner.
- After charging is completed, the charge door is closed and sealed.
- Once operation is initiated, no further charges are made until the next operating cycle (i.e., after the incinerator cools and ash is removed).
- Prior to ignition of the waste, the secondary combustion chamber is preheated. A minimum secondary temperature of 1800°F (980°C) is recommended prior to ignition of the waste in the primary chamber.

The manufacturer should be consulted regarding proper preheat procedures; improper preheat can result in refractory damage.

Intermittent-Duty Incinerators. Intermittent-duty, controlled-air incinerators typically are used for shift type operation. The incinerator must be shut down for ash removal. The charging/operating system is designed to accommodate multiple charges safely throughout the operating cycle rather than relying on a single-batch charge. Either manual or automated charging systems are used.

The following general principles apply for charging intermittent-duty incinerators:

- Stable combustion is best maintained with a constant heat input to the incinerator.
- Frequent, smaller charges are more desirable than one big charge.

- Overcharging (feeding too much waste in a charge) can cause excessive emissions because of rapid volatilization of organic compounds that overload the secondary chamber.
- Feeding too little waste results in inadequate heat input and excessive auxiliary fuel use.
- A recommended charging frequency is 10 to 25 percent of the rated capacity (lb/h) at 5 to 15 minute intervals.
- Another rule of thumb is to recharge the incinerator after the previous charge has been reduced by 50 to 70 percent in volume (as observed through a viewport).
- Charging volume and frequency will vary with waste composition and the incinerator design. Differences in charging procedures are appropriate for small manually fed units and large mechanically fed units. For large systems using mechanical charging, frequent charges will not interrupt incinerator operation because the mechanical system limits entry of excess air. Frequent, smaller charges are desirable. For smaller manually fed units, each time the door is opened, excess air enters and disrupts combustion. Also, opening the door creates a potential safety hazard. Less frequent charging is desirable. However, the charges should not be so large as to overload the incinerator.
- After the last charge of the day is completed, the incinerator is set to initiate burndown. The limiting factor on how long the incinerator can be operated without shutting down is how quickly ash builds up on the hearth. Typically, the operating period during which the incinerator is charged with waste is limited to 12 to 14 hours.

Continuous-duty incinerators. Continuous-duty incinerators typically are large units equipped with mechanical feed systems.

The mechanical feed system often is automatically operated so that the charge is fed on a timed sequence. Proper charging involves:

- Frequent charges of 10 to 25 percent of rated capacity (lb/h) every 5 to 15 minutes.
- Charging frequency may need to be adjusted to accommodate major changes in waste heat value.

CONTROLLING AND MONITORING KEY OPERATING PARAMETERS

The specific controls and monitors for each incinerator will be different. Some incinerators will have mostly manual controls and few monitors. Other incinerators will have highly automated control systems with many monitors to assist the operator. In this section, we will review some basic procedures the operator can follow for controlling and monitoring key operating parameters. How much control you actually have over the operation of your incinerator depends on the specific design and installation of the incinerator.

The operating parameters which we will discuss include:

- Charging rate;
- Primary and secondary chamber temperatures;
- Combustion air levels; and
- Combustion chamber draft.

Charge Rate. The charge rate--or heat input rate--is critical to proper operation and is one parameter over which the operator has direct control. The incinerator must be operated with a charge rate consistent with its design so that the automatic or manual air and temperature controllers can do their job.

Monitoring the charge rate. The charge rate can be easily monitored. It is not necessary to monitor the rate exactly--unless required by regulation.

The operator can monitor the charge rate in several ways:

- Recording the amount and the time of each charge;
- Noting the source and type of waste;
- Observing trends in the primary and secondary temperatures;
- Observing the depth of the waste bed in the primary chamber; and
- Observing ash burnout quality.

1. Using a charging log. Recording the time and amount of each charge is called keeping a "charging log."

When you keep a charging log, you record the time each charge is made and the quantity of each charge (1 bag, 5 bags, 1 hopper, etc.). Monitoring charging in this way should provide sufficient information to determine if charging procedures are consistent and to provide information for making adjustments. For example, if overcharging is the suspected cause of black smoke, it is only necessary to reduce the number of bags charged in each batch and observe whether the reduced size of each load eliminates the emission problem.

If you want to know about how much waste you are charging with each load, you can weigh your loads for a day to get an average weight. In this case, you record the time each charge is made and the weight of the charge. This approach requires a scale. Some mechanical systems will automatically record the time and weight of a charge. Routinely recording the weight of all charges should not be necessary, unless regulations require it. However, this approach is highly recommended if you want to monitor your charging rate.

2. Observing trends in the primary and secondary combustion chamber temperatures. You should monitor primary and secondary combustion chamber temperature trends (that is, whether the temperatures are steady or are rising or falling). This information helps you evaluate whether the charging rate is correct.

It is expected that the temperatures will rise and fall in a cycle after each charge. However, major swings (for example, outside the recommended operating ranges) may be an indication of a need to adjust charging procedures.

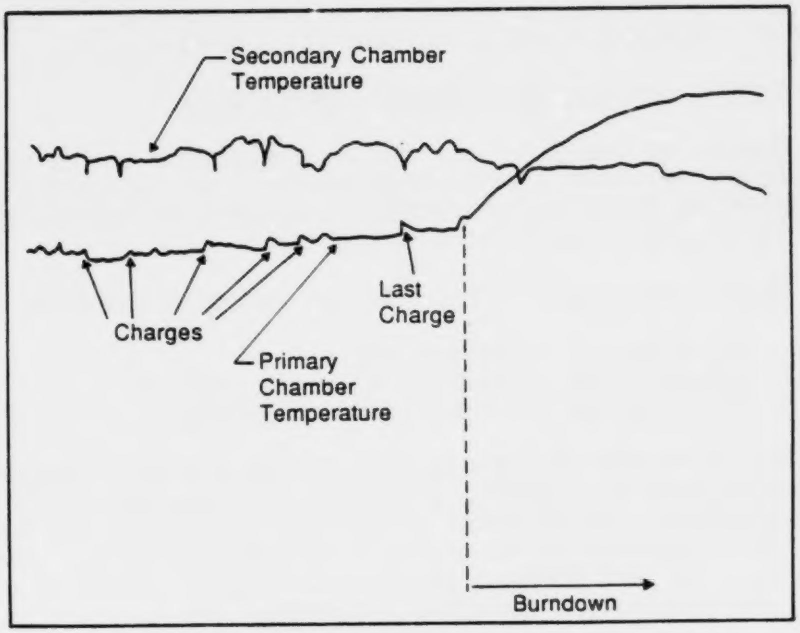
You should look for:

- Primary chamber temperature drop--if the primary chamber temperature falls below the desired low temperature setpoint and the auxiliary fuel burner is activated, the chamber is low on fuel and is overdue for a charge. (This assumes that the automatic combustion air control system is properly operating and that proper air has been provided to the primary chamber). Note: When very wet or low Btu waste is added to the primary chamber, a drop in temperature is expected. Adding more waste will further decrease the temperature.
- Secondary chamber temperature increase--if the secondary temperature begins to rise above the desired high temperature setpoint, the chamber may be receiving more fuel--in the form of combustion gases from the primary chamber--than the automatic air and burner control system can handle. Assuming the primary chamber air control system is properly operating, this situation indicates excess volatile emissions from a charge; i.e., the previous charge was too large or was too soon after the last charge.

Figure 6-1 depicts a temperature record for a controlled-air incinerator charged with a waste containing a significant volatile content. The impact of the charge on the temperatures can be seen. Primary and secondary temperatures as key parameters are further discussed in the next section.

3. Observing the waste bed. If view ports are available in the primary chamber, you can observe the waste bed. If the pile of unburned waste (other than normal ash buildup) inside the chamber is rapidly and steadily increasing in size, then the amount charged is greater than the amount which can be consumed in the same period of time. On the other hand, if all the waste is consumed well in advance of the next charge, it may be desirable to increase the charge size.

4. Observing ash quality. If all the combustible waste is not burned, it may be because the charge rate is too high and not enough time has been provided for complete combustion. Another reason for poor ash quality is insufficient underfire air. The term "burnout" is used to describe the amount of combustible material left in the ash. If all the waste is burned and no combustible material is left in the ash, the burnout is 100 percent. If only half the combustible waste is burned and one-half of the remaining ash is combustible, the burnout is 50 percent; this level of burnout is not good.



TEMPERATURE TREND

Figure 6-1. Example combustion chamber temperature trends--high volatile content waste.[1]

Control of the charge rate. The charge rate can be controlled by you. The rate can be controlled by either charging less waste with each load or by charging less frequently. For example: if an incinerator has an automatic hopper/ram charging system which is automatically controlled to charge one hopper every 10 minutes, the operator can reduce the charging rate simply by not filling the hopper to the top. The other approach would be to change the automatic timer to charge less frequently; for example, every 15 minutes instead of every 10 minutes. If the charge rate is to be increased for a system using a hopper/ram assembly, the frequency of charges would need to be increased (every 7 minutes, for example) because you should not overfill a hopper.

Primary and Secondary Chamber Temperatures.

Monitoring temperatures. You use temperature gauges to monitor the primary and secondary chamber temperatures. All incinerators should have a temperature gauge and, preferably, a temperature recorder. A recorder will assist you in seeing temperature trends.

Controlling temperatures. You can control temperature in three ways:

- Adjusting the charging rate;
- Adjusting the combustion air level; and
- Adjusting the auxiliary burner setpoints.

The importance of charging rate already has been discussed. Adding additional waste will generally increase the temperature; in a controlled-air incinerator, the automatic air control system will act to limit the temperature increase to the desired temperature setpoint. Note: if the fuel has a low heat content, such as pathological wastes or very wet waste, the temperature can actually decrease when a charge is added.

For a controlled-air unit, controlling the combustion air affects the temperature. Adjusting the combustion air is the primary control mechanism used, other than adjusting the charge rate. Increasing the air in the primary chamber increases the primary chamber temperature and increasing the air in the secondary chamber decreases the secondary chamber temperature. Usually, the automatic control system on a controlled-air unit will control the air levels. The automatic control system's operation will be based on:

- A clock timer sequence which operates in conjunction with each batch charge; or
- The temperature output from the thermocouples; or
- Some combination of the above two.

Actual adjustments to air damper settings or time/temperature setpoints normally are not made by you unless problems are persistent. Only properly trained operators should make damper adjustments on an automatic control system.

The final temperature control available to you is use of the auxiliary burners in the primary and secondary chambers. Again, these burners normally are automatically controlled; the burner is activated by a temperature setpoint. Only properly trained operators should adjust setpoints.

Primary Chamber and Secondary Chamber Combustion Air Levels And Stack Gas Oxygen Level.

Monitoring combustion air levels. Two means of monitoring air levels which are available to you are:

- An oxygen monitoring system; and
- Visual observations (indirect indicator).

The only way to actually measure the combustion excess air level is to use an oxygen monitor. Some incinerators have an oxygen monitor installed in the stack to monitor the overall excess air level. When such a monitor is available, you should assure that the combustion gas oxygen remains within the desired range.

Visual observation within the combustion chambers (through sealed glass observation ports) and of the stack gas will assist the operator in determining whether air levels may be incorrect. You should look for the following:

- Primary Chamber--The primary chamber is supposed to operate with deficient oxygen. The waste bed should be burning with a dark red color, and smoke will likely be present. If roaring bright yellow or orange flames are present, too much air is available. The problem may be air infiltration from leaks or improper combustion air settings.
- Secondary Combustion Chamber--The secondary burner flame should be burning with a bright yellow/orange flame and should not be smoking. A smoking flame indicates too little burner air.
- Stack Gas--The stack gas should be clean. Black smoke indicates incomplete combustion caused by insufficient air in the secondary chamber. (This situation is discussed in Session 8).

Control of Combustion Air. The combustion air levels are controlled by adjusting the combustion air dampers. Depending upon the control system, you may or may not have direct control of the air dampers. The air dampers are usually automatically controlled to maintain the desired combustion chamber temperatures. If you suspect persistent problems with combustion air levels, the damper settings should be checked and adjusted by a trained/qualified technician.

In some cases, a manual "emergency" override for automatically controlled systems may be present on the control panel for use when black smoke at the stack indicates incomplete combustion. Such an override will fully open the secondary air damper to allow maximum air while fully closing the damper to the primary chamber to decrease combustion; typically, the override also will shut off the secondary burner.

Incinerator Draft. The draft in the primary chamber must be maintained within the desired operating range. If the draft is too high, entrainment of particulate matter may occur, or air infiltration through leaks may be excessive. If the draft is too low, the chamber may reach a positive pressure, which is not desirable because smoke and hot gases might puff from the chamber door seals. A negative pressure in the incinerator is needed to prevent fugitive emissions.

Monitoring incinerator draft. A draft gauge is required to measure the pressure in the incinerator chamber. Your incinerator may or may not have such a gauge.

Control of incinerator draft. For natural draft systems, the draft may be controlled by a motorized barometric damper or stack damper, or it may be uncontrolled. Depending upon your system, these dampers may be manually controlled or may have an automatic control to maintain a preset draft.

For systems using an induced draft fan, a damper at the fan inlet or outlet is usually used to control the fan suction. Again, the damper may be controlled manually or automatically.

OTHER PARAMETERS TO MONITOR

Other parameters you should monitor include:

- Stack opacity;
- Stack gas carbon monoxide; and
- Burner flame pattern.

Stack Gas Opacity. Stack gas opacity provides an indirect measurement of particulate matter concentration in the stack gas. As particulate matter increases so does opacity.

You should make a habit of observing the stack emissions. If high opacity emissions occur, proper operation of the equipment should be checked and operating procedures should be changed, if necessary. Session 8 further discusses how opacity can be used to identify combustion problems and some possible operating changes to correct the problems.

If your incinerator is equipped with a transmissometer (continuous monitor for opacity) you should learn the acceptable opacity range and frequently check the instrument data to assure that the incinerator is operating within the acceptable range; pay attention to the "high opacity alarm" when it goes off.

Combustion Gas Carbon Monoxide. Carbon monoxide gas (CO) is formed during incomplete combustion. Excessive levels indicate that a poor combustion condition exists. Levels greater than 100 ppm are usually considered excessive. Your State may specifically regulate the level of CO.

The CO level of the combustion gas can be monitored by an instrument. If your incinerator continuously monitors CO, you should routinely check the levels to assure they stay within the acceptable range. If they do not, changes in your charging procedures or adjustments to combustion air levels are probably necessary. If no CO instrument is installed, you cannot determine CO levels.

Burner Flame Pattern. If sealed observation ports are available, you should check the burner flame pattern daily. The burner flame should:

- Be bright yellow/orange;
- Not smoke;
- Not move back and forth abruptly; and
- Not hit the refractory walls.

Figures 6-2a, 6-2b, and 6-2c schematically show proper and improper flame patterns. If you suspect a burner problem, report the problem to the maintenance department.

SUMMARY OF CONTROL AND MONITORING TECHNIQUES FOR CONTROLLED-AIR INCINERATORS

The control and monitoring of a controlled-air incinerator is complex. Five of the key operating parameters that are very interrelated are:

- Charge rate;
- Primary chamber temperature;
- Secondary chamber temperature;
- Primary chamber combustion air level; and
- Secondary chamber combustion air level.

A typical controlled-air incinerator system will have some type of automatic control system which controls both the temperature and amount of combustion air to both chambers. The system monitors the chamber temperatures and controls the combustion air levels and auxiliary burners to maintain the desired setpoints. For the automatic control system to operate properly, the incinerator must be charged with an amount of waste consistent with the incinerator's design capacity.

The charge rate to the incinerator is the single most important parameter that you can control. The operator monitors combustion chamber temperatures and temperature trends to evaluate whether the charge rate is appropriate. If an oxygen monitor is available, the stack gas oxygen level is monitored to confirm that combustion air levels are consistent with good operating practice.

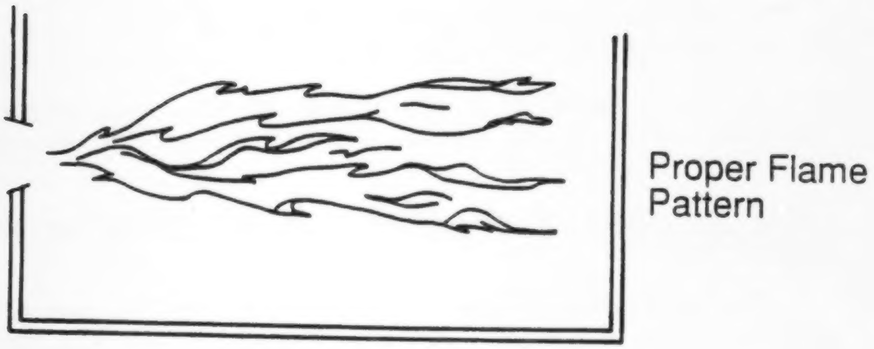

Proper Flame
Pattern

Figure 6-2a. Proper flame pattern.[22]

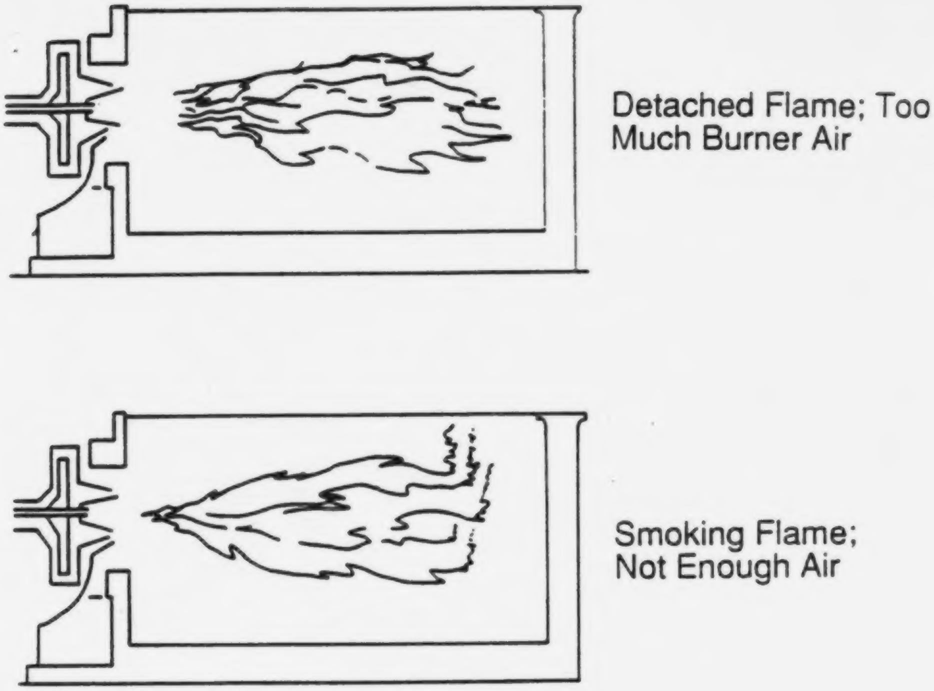

Detached Flame; Too Much Burner Air
Smoking Flame; Not Enough Air

Figure 6-2b. Improper burner air.[22]

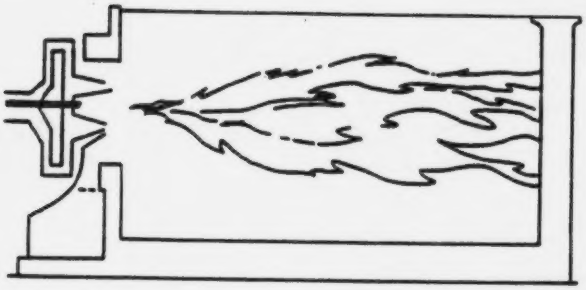


Figure 6-2c. Flame impingement.[22]

If monitored values such as temperature, ash quality, and stack opacity indicate operational problems, then adjustments to the automatic control system should be considered. These adjustments should only be made by someone who is properly trained and qualified. Ideally, you will be properly trained and qualified to make minor adjustments to the control system settings--such as damper settings and setpoints. The ability to understand and make such adjustments will allow you to control and operate the system for optimum performance.

PROPER ASH HANDLING PROCEDURES

Batch-feed and intermittent-duty incinerators require that the ash be removed from the incinerator at the end of each incineration cycle. (Sometimes, if the incineration cycle is short, it will not be necessary to clean out the ash after each cycle.) The following are guidelines for good operating procedures when ash is manually removed:

- The incinerator should be allowed to cool sufficiently so that it is safe for the operator to remove the ash. This cooling can take as long as 8 hours.
- You should exercise extreme caution since the refractory may still be hot and the ash may contain local hot spots, as well as sharp objects.
- The ash and combustion chamber should not be sprayed with water to cool the chamber because this can damage the refractory.
- A flat, blunt shovel or raking tool, not sharp objects that can damage the refractory, should be used for removing the ash.
- Avoid pushing ash into the underfire air ports.
- Avoid bumping or knocking burner nozzle assemblies or thermocouple housings.
- Place the ash into a noncombustible container such as metal, not cardboard.
- After the ash has been removed, dampen the ash with water to further cool the ash and minimize fugitive (windblown) emissions.
- Assure that the ash door is securely closed and the seal is good; visually inspect the condition of the sealing material and make sure nothing (such as a piece of ash) is caught in the door.
- Store the removed ash in a safe manner until disposal; cover the ash container to prevent windblown dust.
- Discard the ash according to approved procedures (according to your permit).

Continuous-duty incinerators have automatic ash removal systems. Generally, your job is to assure that the system is properly operating. This includes:

- Being on the lookout for jams in conveyor systems.
- Assuring that water flow is maintained to quench sprays and pits.
- Assuring that the water level in the quench pit is maintained so that the water seal with the incinerator is not broken.
- Assuring that full ash containers are removed and replaced with empty containers.

- Inspecting ash quality, noting problems, and determining whether operating changes are required.

STARTUP AND SHUTDOWN PROCEDURES

Startup and shutdown of an incinerator typically requires special steps to be taken. Specific manufacturer's instructions should be followed. Some general recommended procedures are listed below.

Single-batch feed incinerators.

Startup:

- Remove the ash from the previous cycle;
- Charge the incinerator; do not overcharge;
- Seal the charge door;
- Preheat the secondary combustion chamber to a predetermined temperature (1800°F [980°C] is recommended);
  The manufacturer should be consulted regarding proper preheat procedures; improper preheat can result in refractory damage. Note: If the incinerator is overloaded and the waste in the primary chamber enters the air passageway to the secondary chamber, the waste may self-ignite during the preheat period. This situation should be avoided; and
- Activate the primary chamber combustion air and burner to ignite the waste.

Shutdown:

- After the waste burns down and all volatiles have been released, the final burndown period is initiated.
  - -- Increase the primary combustion air level to improve combustion of the fixed carbon.
  - -- Maintain the temperature in the primary chamber at a minimum temperature using the auxiliary burner for a predetermined length of time to assure that the fixed carbon is combusted.
  - -- When the burndown period is complete, as indicated by maintaining the preset temperature in the primary chamber for a preset period of time, the cooldown period is initiated.
  - -- Shut down the primary and secondary burners.
  - -- Keep the combustion blowers operating to assist in cooldown.

Intermittent-Duty Incinerators. The general procedures for startup and shutdown of an intermittent-duty incinerator are as follows.

Startup:

- Ignite the primary and secondary burners and preheat the combustion chambers.

- After the secondary temperature has reached a minimum predetermined temperature (1800°F [980°C] is recommended), activate the combustion air blowers. The manufacturer should be consulted regarding proper preheat procedures; improper preheat can result in refractory damage.
- Charge the incinerator.

Shutdown. After the last charge of the day, the incinerator is set to initiate a burndown/cooldown procedure. Depending upon the incinerator, this sequence will be manually or automatically activated and controlled. The burndown/cooldown procedure is essentially the same as the procedure discussed for the batch-type incinerator.

Continuous Duty Incinerators. The general startup and shutdown procedures for continuous-duty incinerators are:

Startup. The startup procedure is essentially the same as for intermittent-duty incinerators. The combustion chambers should be preheated before charging the first load of waste.

Shutdown. Shutdown of a continuous-duty incinerator involves stopping the charging process and maintaining temperatures in the combustion chamber until the remaining waste burns down to ash and is finally discharged from the system in a normal manner.

Special Considerations.

Pathological waste. If the waste being incinerated is pathological waste or contains a large amount of pathological waste, it will be necessary to leave the ignition burner on during the entire process. In fact, incinerators intended for burning primarily pathological waste will usually have additional burners in the primary chamber.

You should remember:

- To destroy pathological waste efficiently, the waste must be directly exposed to the burner flame.
- Loading pathological waste into the incinerator in large piles will result in inefficient combustion. A single layer of waste should be placed onto the hearth.
- If large volumes of pathological waste are to be incinerated, an incinerator specially designed for pathological waste should be used.

DO'S AND DON'TS FOR OPERATING A CONTROLLED-AIR INCINERATOR

DO:

- Preheat the secondary chamber before igniting the waste;
- Pay careful attention to charging procedures and charging rates;
- Look out for and pay attention to extreme differences in waste characteristics;

- Monitor combustion chamber temperatures and learn to recognize trends that are good and trends that indicate a problem;
- Routinely monitor stack opacity, especially after charging;
- Pay attention to the other monitors you may have at your facility, such as oxygen, CO, and opacity;
- Make good use of viewports to visually check the combustion chambers and learn to recognize problems;
- Pay attention to operation of your auxiliary burners; are they properly cycling on and off? At the right time?
- Inspect the ash quality. If visual inspection indicates poor burnout--large recognizable pieces of combustible waste such as hospital scrubs--check your equipment and/or make changes to operating procedures/conditions;
- Note problems that indicate the need for adjustment of automatic control system dampers and setpoints--if you are not trained to make adjustments, call maintenance;
- Handle and dispose of the bottom ash properly and carefully;
- Operate the primary burner(s) when burning pathological waste.

DON'T:

- Overcharge the incinerator; and
- Charge large amounts of pathological waste to the incinerator unless it is designed for pathological waste.

OPERATION OF MULTIPLE-CHAMBER INCINERATORS

INTRODUCTION

Multiple-chamber incinerators may have a grate or a fixed (solid) hearth in the primary chamber. Incinerators with grates are designed for use with general refuse, and combustion of medical infectious wastes containing significant quantities of fluids is not recommended in this type incinerator.

Multiple-chamber incinerators designed specifically for burning pathological wastes always have a solid hearth. Caution should be exercised when burning general refuse/red bag wastes in an incinerator designed specifically for pathological waste. Red bag wastes likely will contain much more volatile combustible material than pathological wastes and will have a higher heat value (Btu/lb). Overcharging the incinerator with red bag waste will result in excess emissions. The proper charging rate for the waste being burned should be carefully determined by trained personnel. Charging procedures consistent with the type of waste being charged should be established.

PROPER WASTE CHARGING PROCEDURES

Most multiple-chamber incinerators used for hospital wastes are designed for intermittent duty operation. Typically, the waste is charged by hand to the incinerator through the open charging door or by a mechanical charging system such a hopper/ram.

Remember that the heat input rate to an incinerator is a very important parameter because the incinerator is designed for a specific heat input rate. The heat input from the waste is determined by the amount of waste and the heat content of that waste. Because the heat content of red bag waste and pathological waste is so different, operation of an incinerator when burning these two types of wastes is different. Proper charging procedures for both types of waste are discussed below.

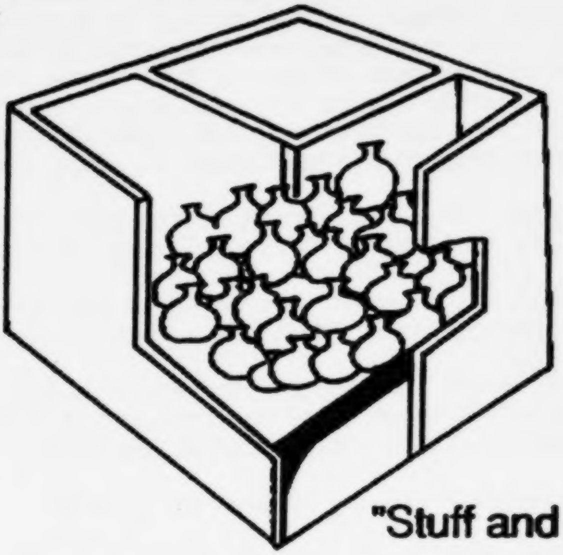
Red Bag Waste. The heat content of red bag waste is variable, depending upon the contents of the bag. Proper operation dictates that:

- Sufficient waste should be charged to the incinerator to sustain the desired temperature without excessive use of the primary burner; and
- To maintain the incinerator chamber below the upper temperature limit and to prevent emissions, the charge rate should not exceed the capacity of the incinerator at any time.

Therefore, recommended charging procedures include:

- Use of frequent, small batches rather than one large batch. The objective is to avoid causing a rapid release of volatile compounds that exceeds the combustion capacity of the incinerator. The frequency and size of each charge will be determined by the incinerator you have and the type of waste. A recommended procedure is to charge about 10 percent of the rated capacity (lb/h) every 15 minutes.
- Keeping a fairly consistent waste bed in the incinerator. The incinerator should not be jammed full, nor should it be empty.
- Avoiding "stuffing and burning" in the incinerator; that is, do not fill the incinerator chamber to full capacity, floor to ceiling, ignite the waste, and allow the incinerator to operate unattended. The proper charging of frequent, small batches versus the improper "stuff and burn" charging approach is illustrated in Figure 6-3.
- When recharging the incinerator:
    - Make sure the primary burner is turned off.
    - The waste bed should be stoked, if necessary, and partially burned waste from the previous charges should be pushed towards the back of the hearth. The new waste charge should be fed to the front end of the hearth (near the charge door). This procedure allows good exposure of the partially combusted waste to the overfire air and allows a good flame from the waste bed to be maintained. On the other hand, if cold, new waste is thrown on top of the existing waste bed, it partially smothers the burning bed which can result in increased emissions. These proper and improper recharging procedures are shown in Figure 6-4.

Pathological Waste. Pathological waste has a low heat content, high moisture content, and contains a low percentage of volatiles. The waste must be exposed to the auxiliary burners to be combusted. The following charging procedures are recommended.



"Stuff and Burn"

Frequent Small Charges

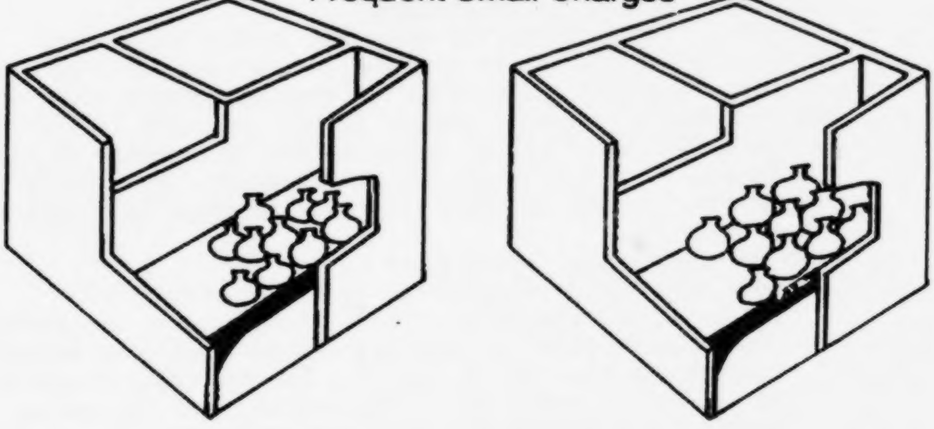
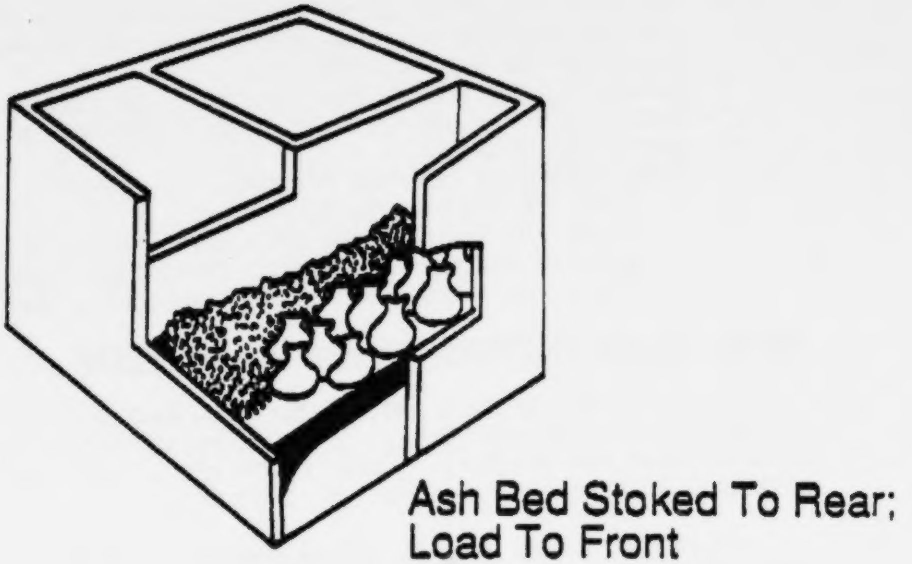


Figure 6-3. Proper and improper charge procedures.


Ash Bed Stoked To Rear;
Load To Front

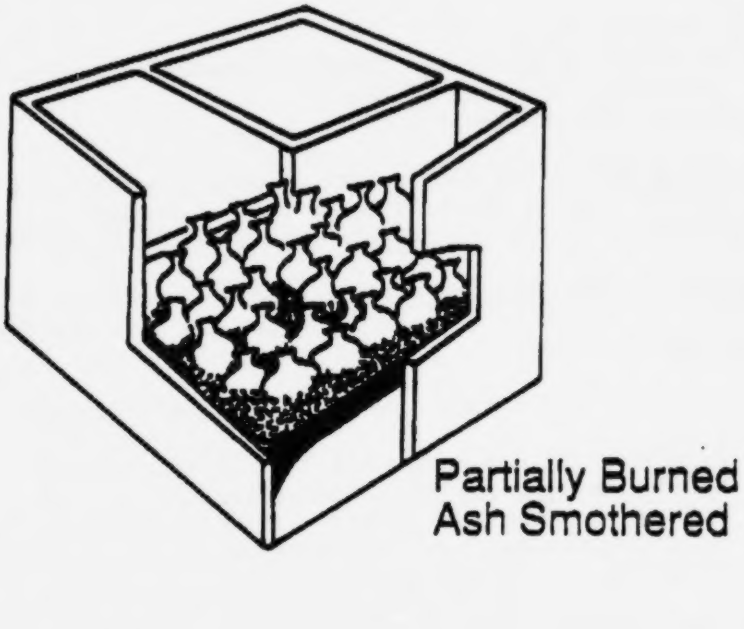

Partially Burned
Ash Smothered

Figure 6-4. Proper and improper charging: waste bed distribution.

- The waste should be placed on the hearth in an even layer that provides maximum exposure to the burner(s) flame(s). The waste should not be deeply piled.
- Recharging the incinerator should not be done until considerable reduction in volume (greater than 75 percent) of the previous charge has occurred.
- When recharging the incinerator:
  -- Turn off the primary burner(s);
  -- Place the fresh charge in a layer on top of the ash bed to provide maximum exposure to the burner flame(s); and
  -- Close the charge door before restarting the primary burner(s).

CONTROLLING AND MONITORING KEY OPERATING PARAMETERS

The specific controls and monitors for each multiple-chamber incinerator will be different. Some incinerators have mostly manual controls with few monitors. Some incinerators have more automated controls and monitors to assist the operator.

In this section, we will review some basic steps you can take for controlling and monitoring the key operating parameters. Specific details of control and how much control you actually have over the operation of your incinerator depends on the specific incinerator.

The operating parameters discussed below include:

- Charging rate;
- Primary and secondary combustion chamber temperatures;
- Combustion air levels; and
- Combustion chamber draft.

Charging Rate. The single most important operating parameter that you can easily control is charging of the incinerator. The incinerator must be operated with a charge rate consistent with its design capacity.

Monitoring the charging rate. The charge rate can be easily monitored. It is not necessary to monitor the rate exactly--unless required by regulation.

The operator can monitor the charging rate in several ways:

- Recording the amount and the time of each charge;
- Noting the type and source of wastes;
- Monitoring combustion chamber temperature trends;
- Observing the depth of the waste bed in the primary chamber; and
- Observing ash burnout quality.

1. Charging log. Recording the time and amount of each charge is called keeping a "charging log."

Record the time when each charge is made and the quantity of each charge (1 bag, 5 bags, etc.). Monitoring charging in this way should provide sufficient information to determine if charging procedures are consistent and to make adjustments. For example, if overcharging is suspected, it is only necessary to reduce the number of bags charged in each batch. If you want to know the amount of waste you are charging with each load, you can weigh your loads for a day to get an average weight. Record the time each charge is made and its weight. This approach requires a scale. Routinely recording the weight of all charges should not be necessary, unless regulations require it.

2. Observing trends in the primary and secondary combustion chamber temperatures. You should monitor primary and secondary combustion chamber temperature trends (that is, whether the temperatures are steady, rising, or falling). This information helps you evaluate whether the charging rate is correct. It is expected that the temperatures will rise and fall in a cycle after each charge. However, major swings in temperature may be an indication of a need to change charging procedures.

You should look for:

- Primary or secondary chamber temperature drop--if the primary chamber temperature is falling towards the lower temperature limit, this indicates that the incinerator is low on waste and it is time to recharge; the primary chamber burner should cycle on when the lower temperature limit is reached.
- Primary or secondary chamber temperature increase--if the primary chamber temperature is rising towards or exceeds the upper temperature limit, additional charges should be delayed.

3. Observing the waste bed. If view ports in the primary chamber are available, you can observe the waste bed. If the pile of unburned waste (in excess of the ash) inside the chamber is steadily increasing in size, then the amount charged is greater than the amount which can be consumed in the same period of time. The charge rate should be reduced. On the other hand, if all the waste is consumed well in advance of the next charge, it may be desirable to increase the charge rate. If view ports are not available, the bed depth can be observed when the charging door is opened. If most of the previous charge is still unburned, do not recharge.

4. Observing ash quality. If all the combustible waste is not burned and recognizable pieces of waste are found in the ash, it may be because the charge rate is too high and not enough time has been provided for complete combustion. You can evaluate ash quality by simply looking at the ash and determining whether complete or near complete combustion has occurred. If recognizable pieces of combustible waste--such as magazines, plastic tubing, pieces of scrub gowns--are seen in the ash, the ash quality is poor. You should expect to see recognizable noncombustible objects such as bottles and cans.

Another way to visually evaluate ash quality is by the color of the ash. If the ash is black, it probably contains a lot of unburned carbon. Ash that is light gray or white, indicates better burnout.

5. Observing the stack emissions. When black smoke is emitted from the stack after charging, the amount charged probably was too much. The incinerator does not have the capacity to combust all the volatiles released. This situation may be correctable by increasing the secondary combustion air. If increasing the secondary combustion air does not alleviate the problem, the size of the charge should be decreased.

Control of the charging rate. The charging rate is probably the easiest parameter for you to control. The rate can be controlled by changing either the amount of waste charged with each load or by changing the charging frequency.

Primary and Secondary Chamber Temperature.

Monitoring temperatures. You use temperature gauges to monitor the primary and secondary chamber temperatures. All incinerators should have a temperature gauge and preferably a temperature recorder. A temperature recorder allows you to monitor trends in temperature.

Control of temperatures. You can control temperature by controlling three parameters:

- Charging rate;
- Combustion air level; and
- Auxiliary burner operation.

The importance of charging rate has already been discussed. For a multiple-chamber incinerator, you essentially control temperature by controlling the charging rate. Increasing the waste feed rate increases temperature; decreasing the waste feed rate decreases temperature. You must balance the charging rate and air supply to sustain the desired temperature without causing emissions. If sufficient temperature cannot be maintained in the primary and secondary chambers, either the charging rate is too low, insufficient heat is being added by the auxiliary burner, or the excess air levels are too high. Remember, as additional excess air is added, it cools the combustion gases; this is one of the reasons that incinerator draft should be closely monitored.

The combustion air levels are adjusted by opening or closing the dampers controlling the overfire air. Generally, opening the dampers allows more air to enter the incinerator. Actual control of the air depends on the type of combustion air system used, natural draft or forced draft. The primary auxiliary burner can be used to increase temperatures, if necessary.

For pathological incinerators, the primary and secondary burners must be used to control incinerator temperature since little or no heat input is derived from the waste. The combustion chamber temperatures are increased or decreased by increasing or decreasing the auxiliary firing rate in the primary chamber. If excess fuel usage is noted or proper temperatures cannot be sustained, the combustion air settings should be checked. Too much excess air will result in greater fuel usage. Since waste properties (heat content and moisture) will not normally change for pathological wastes, the incinerator should operate steadily once it is properly adjusted. Once the air settings are properly adjusted, they should not have to be frequently changed.

Primary and Secondary Combustion Air Levels and Combustion Gas Oxygen Level.

Monitoring of combustion air. Three ways that you can monitor combustion air levels include:

- Using an oxygen monitoring system;
- Observing damper settings; and
- Observing stack gas opacity.

Oxygen monitors. An oxygen monitor provides the most accurate means for determining the excess air level. Some incinerators have an oxygen monitor installed in the stack to monitor the overall multiple-chamber level. When such a monitor is installed, the operator should assure that the oxygen remains in the desired range (11 to 16 percent).

Damper settings. Some older multiple-chamber incinerators use natural draft openings for the combustion air. The operator can monitor the combustion air rate by the relative damper setting; a damper that is fully open allows more combustion air to enter the incinerator than a damper that is half open. Although a damper setting does not indicate the actual combustion air rate or the excess air level, it does provide a relative indicator. Other multiple-chamber incinerators use a forced air blower to supply overfire combustion air. The damper setting on the blower provides a relative indicator of the combustion air being supplied; more air will be supplied when the damper is open relative to when the damper is closed.

Visual observation of stack gas opacity. The stack gas should be clean. Black smoke indicates incomplete combustion caused by insufficient air.

Control of combustion air. The combustion air levels are controlled by adjusting the combustion air dampers. The operator controls the amount of air entering the incinerator by opening or closing the dampers. Note that if the operator does not have a direct way to measure the combustion air levels, such as an oxygen monitor, it is difficult to determine the most desirable damper setting. Consequently, if your dampers have been preset by a technician using monitoring equipment to determine the excess air levels, it may not be appropriate for you to adjust the damper setting. You should not adjust damper settings unless you have been properly trained to do so.

Incinerator Draft. It is important to keep a negative pressure (draft) in the incinerator to maintain combustion airflow through the incinerator and to prevent fugitive emissions. However, excessive draft can result in entrainment of particulate matter which will exit the incinerator combustion stack.

Monitoring draft. A draft gauge is required to measure the negative pressure in the incinerator chamber.

Controlling draft. The draft within the chamber is controlled by adjusting control dampers on the incinerator. For incinerators operating under natural draft conditions, a damper in the stack gas flue may be used to control draft; or a mechanized barometric damper often is used to control the incinerator draft automatically to a preset level. If the incinerator has an induced draft fan, dampers at the inlet or outlet of the fan typically are used to control draft. These dampers may be manually controlled, or may be mechanized to automatically adjust and control incinerator draft to a preset level.

Other Parameters to Monitor. Other parameters you should monitor include:

- Stack gas opacity;
- Stack gas carbon monoxide; and
- Burner flame pattern.

These items were discussed in the previous section on controlled-air incineration, and the discussion is not repeated here.

SUMMARY OF CONTROL AND MONITORING TECHNIQUES FOR MULTIPLE-CHAMBER INCINERATORS

The primary control parameter for a multiple-chamber incinerator is the charging rate. Since both the primary and secondary chambers operate with excess air, the combustion rate in the primary chamber cannot be strictly controlled. Consequently, proper charging of the incinerator is essential. The operator uses combustion chamber temperatures to monitor incinerator operation. The charging rate (heat input) must be consistent with incinerator capacity. The primary chamber auxiliary burner typically will be set to cycle on when insufficient heat input is provided by the waste. Adjustments to the air dampers also may be required to maintain the proper draft and combustion air levels; damper control is often automatically controlled by a mechanized system.

For pathological waste incinerators, the primary control variable is the heat input rate from the primary chamber burner(s). Since the heat content of the waste is insufficient to sustain combustion, the auxiliary burners operate continuously, and the combustion air levels required remain essentially constant.

PROPER ASH HANDLING PROCEDURES

Ash is manually removed by the operator at the end of each incineration cycle. Proper ash handling procedures for multiple-chamber incinerators are essentially the same as for batch and intermittent-duty, controlled-air incinerators. The following are guidelines for good operating procedures for manually removing ash from the incinerator:

- Allow the incinerator to cool sufficiently so that it is safe for the operator to remove the ash. This cooling can take as long as 8 hours or more.
- Do not spray the ash and combustion chamber with water to cool the chamber because this can damage the refractory.
- Use a flat blunt shovel or raking tool, not sharp objects that can damage the refractory, for removing the ash. You should exercise extreme caution since the refractory may still be hot and the ash may contain local hot spots, as well as sharp objects.
- Avoid bumping or knocking of burner nozzle assemblies or thermocouple housings.
- Place the ash into a noncombustible container such as a metal container, not cardboard.
- Dampen the ash with water to cool the ash and minimize fugitive (windblown) emissions.
- Store the ash in a safe manner until final disposal. Cover the ash container to prevent windblown dust.
- Discard the ash according to approved procedures (according to your permit).

STARTUP AND SHUTDOWN PROCEDURES

Startup and shutdown of the incinerator requires some special steps to be taken to minimize emissions. Specific manufacturer's instructions should be consulted. The following are recommended procedures for good operating practice.

Startup

- Inspect the ash from the previous cycle. Is ash quality acceptable? If not, adjustments to operating procedures will be required. Remove the ash from the previous incineration cycle.
- Preheat the secondary combustion chamber to the minimum recommended temperature (e.g., 1800°F [980°C]).
- Charge the incinerator with the first charge.
- Close the door.
- Ignite the waste using the primary burner.

Shutdown

- After the waste in the last charge has burned down, the primary chamber temperature will be maintained by the auxiliary burner at the preset minimum combustion chamber temperature. This period is called the burndown period.
- The burndown period is continued for a predetermined length of time or until visual inspection indicates that burnout of the waste bed is sufficient. When the burndown period is completed, the primary and secondary burners are shut down.

For pathological incinerators, shutdown of the incinerator is determined by inspecting the ash bed. If all the material has been combusted, shut down the primary and secondary burners. If waste still

REVIEW EXERCISE

8. A monitor(s) that would be helpful to an operator for controlling a multiple-chamber incinerator is:

   a. A combustion gas oxygen monitor
   b. An opacity monitor
   c. All of the above
   d. a and b

9. Key operating parameters for controlled-air incinerators include: ______, ________, and _____________

10. Three key operating parameters for multiple-chamber incinerators are ______, _____, and _____.

11. The temperature within the secondary combustion chamber should be:

   a. Maintained below 2200°F
   b. Maintained above 1800°F
   c. Disregarded
   d. None of the above
   e. a and b

7. False. The secondary chamber should always be preheated.

8. a. An oxygen monitor allows the operator to monitor excess air levels.

9. Any of the following:

   Primary chamber temperature, secondary chamber temperature, charging rate, combustion air level, combustion gas oxygen concentration, or combustion chamber draft.

10. Any three of the following:

   Primary chamber temperature, secondary chamber temperature, charge rate, total combustion air level, combustion gas oxygen concentration, chamber draft.

- Allow the incinerator to cool sufficiently so that it is safe for the operator to remove the ash. This cooling can take as long as 8 hours or more.
- Do not spray the ash and combustion chamber with water to cool the chamber because this can damage the refractory.
- Use a flat blunt shovel or raking tool, not sharp objects that can damage the refractory, for removing the ash. You should exercise extreme caution since the refractory may still be hot and the ash may contain local hot spots, as well as sharp objects.
- Avoid bumping or knocking of burner nozzle assemblies or thermocouple housings.
- Place the ash into a noncombustible container such as a metal container, not cardboard.
- Dampen the ash with water to cool the ash and minimize fugitive (windblown) emissions.
- Store the ash in a safe manner until final disposal. Cover the ash container to prevent windblown dust.
- Discard the ash according to approved procedures (according to your permit).

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- Close the door.
- Ignite the waste using the primary burner.

Shutdown

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- The burndown period is continued for a predetermined length of time or until visual inspection indicates that burnout of the waste bed is sufficient. When the burndown period is completed, the primary and secondary burners are shut down.

For pathological incinerators, shutdown of the incinerator is determined by inspecting the ash bed. If all the material has been combusted, shut down the primary and secondary burners. If waste still remains on the hearth, continue to incinerate until acceptable burndown has occurred.

DO'S AND DON'TS FOR OPERATING A MULTIPLE-CHAMBER INCINERATOR

DO:

- Preheat the secondary chamber prior to startup
- Pay careful attention to charging procedures and rates
- Shut off the primary burner when charging
- Monitor combustion chamber temperatures and learn to recognize trends that indicate proper operation and trends that indicate problems
- Monitor combustion chamber draft and maintain draft within the proper operating range
- Routinely monitor stack gas opacity, especially after charging
- Pay attention to operation of your auxiliary burners; are they properly cycling on and off? At the right times?
- Properly and carefully dispose of the ash
- Inspect the ash. Does visual inspection indicate poor burnout--are pieces of uncombusted waste present? If ash quality is poor, make changes to operating procedures/conditions
- For pathological wastes, operate the primary burner at all times

DON'T:

- Overcharge the incinerator
- Deeply pile pathological waste on the hearth

REVIEW EXERCISE

8. A monitor(s) that would be helpful to an operator for controlling a multiple-chamber incinerator is: a. A combustion gas oxygen monitor b. An opacity monitor c. All of the above d. a and b	7. False. The secondary chamber should always be preheated.
	8. a. An oxygen monitor allows the operator to monitor excess air levels.
9. Key operating parameters for controlled-air incinerators include: _______, ________, and _____________	
10. Three key operating parameters for multiple-chamber incinerators are ______, _____, and _____.	9. Any of the following: Primary chamber temperature, secondary chamber temperature, charging rate, combustion air level, combustion gas oxygen concentration, or combustion chamber draft.
11. The temperature within the secondary combustion chamber should be: a. Maintained below 2200°F b. Maintained above 1800°F c. Disregarded d. None of the above e. a and b	10. Any three of the following: Primary chamber temperature, secondary chamber temperature, charge rate, total combustion air level, combustion gas oxygen concentration, chamber draft.

REVIEW EXERCISE

1. The real concern about infectious (red bag) waste is that:
    a. It stinks
    b. It may contain organisms that can cause disease
    c. It is messy

2. Proper waste handling includes:
    a. Handling the waste as little as possible
    b. Using strong containers
    c. Not overstuffing the charging hopper
    d. Properly storing the waste
    e. All of the above

3. It is not the operator's problem if bags spill and break. True or False?

4. Multiple-chamber incinerators may use either ____ ____ openings or ____ draft blowers to provide combustion air.

5. A major way that the operator can control the incinerator is to control the ____________ ______________.

6. The most important parameters that the operator should rely upon to monitor operation are the primary and secondary chamber temperatures. True or False?

7. When burning pathological waste it is not necessary to preheat the secondary combustion chamber. True or False?

1. b. It may contain organisms that cause disease

2. e. All of the above

3. False. The operator should be concerned about broken bags and report problems to the appropriate hospital personnel.

4. natural draft, forced

5. charging rate

6. True. The temperatures indicate operating trends.

REVIEW EXERCISE

12. The operator should pay attention to _____ in the combustion chamber temperatures.	11. e. a and b
13. It is always better to charge the incinerator with very large charges and as few times as possible in a day. True or False?	12. trends or changes
14. During startup of the incinerator, the operator should ______ the secondary combustion chamber.	13. False
15. Because pathological waste has a _______ heat content and high _______ - content, it requires special charging and operating procedures.	14. preheat
19. The operator should routinely look at the stack outlet to monitor the stack gas ________.	18. low, moisture
	19. opacity

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SESSION 7.
AIR POLLUTION CONTROL SYSTEMS OPERATION

SESSION 7. AIR POLLUTION CONTROL SYSTEMS OPERATION

TABLE OF CONTENTS

Page

SESSION GOAL AND OBJECTIVES 7-1

Introduction 7-1

WET SCRUBBERS - GENERAL 7-1

Scrubber Operation 7-1

VENTURI SCRUBBERS 7-2

Key Operating Parameters 7-2
Recommended Operating Ranges for Key Parameters 7-2
Monitoring of Key Parameters 7-2
Venturi Scrubber Operation 7-3
Venturi Scrubber Startup 7-3
Venturi Scrubber Shutdown 7-3

PACKED-BED SCRUBBER 7-3

Key Operating Parameters 7-3
Recommended Operating Ranges for Key Parameters 7-4
Monitoring of Key Parameters 7-4
Packed-Bed Scrubber Operation 7-4
Packed-Bed Scrubber Startup and Shutdown 7-4

FABRIC FILTERS 7-4

Key Operating Parameters 7-4
Recommended Operating Ranges for Key Parameters 7-5
Monitoring of Key Parameters 7-5
Fabric Filter Operation 7-6
Fabric Filter Startup 7-6
Fabric Filter Shutdown 7-6

DRY SCRUBBERS - GENERAL 7-7

Dry Scrubber Operation 7-7

SPRAY DRYERS 7-7

Key Operating Parameters 7-7
Recommended Operating Ranges for Key Parameters 7-7
Monitoring of Key Parameters 7-7
Spray Dryer Operation 7-8
Spray Dryer Startup 7-8
Spray Dryer Shutdown 7-8

TABLE OF CONTENTS (continued)

Page

DRY INJECTION.. 7-8

Key Operation Parameters... 7-8
Recommended Operating Ranges for Key Parameters.................. 7-9
Monitoring of Key Parameters..................................... 7-9
Dry Injection Operation.. 7-9
Dry Injection Startup.. 7-9
Dry Injection Shutdown... 7-9

ELECTROSTATIC PRECIPITATORS...................................... 7-9

Key Operating Parameters... 7-9
Recommended Operating Ranges for Key Parameters.................. 7-10
Monitoring of Key Parameters..................................... 7-10
ESP Operation.. 7-11
ESP Startup.. 7-12
ESP Shutdown... 7-12

REFERENCES... 7-16

SESSION 7.
AIR POLLUTION CONTROL SYSTEMS OPERATION

SESSION GOAL AND OBJECTIVES

GOAL

To familiarize you with:

- The key operating parameters and how to monitor those parameters for the various types of air pollution control systems (APCS) on hospital incinerators; and
- Special operating considerations for APCS startup and shutdown.

OBJECTIVES

Upon completing this session, you should be able to:

1. Identify the key operational parameters for your APCS;
2. Describe the operational ranges considered acceptable for these parameters;
3. Describe how to monitor the key parameters; and
4. Name the steps to take to ensure proper operation of your APCS during startup and shutdown.

INTRODUCTION

During this session we will discuss the key operational parameters, monitoring of those parameters, and startup and shutdown of the following APCS:

- Wet scrubbers
  - -- venturi scrubber
  - -- packed-bed scrubber
  - -- spray towers
- Fabric filters
- Dry scrubbers
  - -- spray dryer
  - -- dry injection scrubber
- Electrostatic precipitators

WET SCRUBBERS - GENERAL

SCRUBBER OPERATION

Many of the key operating parameters, monitoring methods, and operation techniques are the same for both venturi and packed-bed scrubbers. Because of their greater complexity, venturi scrubbers will be addressed first in the following discussion. The discussion of packed-bed scrubbers will focus only on those items that differ from venturi scrubbers. Spray towers are relatively simple to operate, requiring only that a proper liquid flow rate be maintained. Spray towers will not be discussed separately.

VENTURI SCRUBBERS

KEY OPERATING PARAMETERS

The key operating parameters that are necessary for effective operation of a venturi scrubber are liquid supply, energy as measured by pressure drop (ΔP), and suspended solids in the scrubbing water.

RECOMMENDED OPERATING RANGES FOR KEY PARAMETERS

Proper operation of a venturi scrubber requires that scrubber ΔP, water supply, and solids content be maintained within acceptable ranges as specified by the manufacturer or by the air agency permit specifications. Recommended ranges of the parameters are:

- Pressure drop--20 to 30 in. w.c. (5.0 to 7.5 kPa)
- Liquid supply--7 to 10 gallons per thousand actual cubic feet (gal/1,000 acf) (0.9 to 1.3 liters per actual cubic meter [ℓ/m^3])
- Solids content--0 to 3 percent

MONITORING OF KEY PARAMETERS

To ensure proper operation of a venturi scrubber, the operator must monitor the key operating parameters and determine the pressure drop and liquid supply.

- Scrubber parameters which can be monitored by the operator include:
  - -- venturi pressure drop;
  - -- liquid flow rate; and
  - -- fan static pressure, rpm, or amperage.
- Pressure drop can usually be monitored directly from installed gauges or manometers.
- The liquid supply can be obtained by comparing the liquid flow rate, which is usually indicated by installed gauges, with the gas flow rate. The gas flow rate can be obtained from fan specifications, which relate gas flow rate to either fan static pressure, rpm, or amperage. At least one of these fan parameters is usually readily available from manufacturer installed gauges.
- Suspended solids content is not easily measured. Acceptable levels are usually obtained by maintaining adequate scrubbing liquid recirculation rates.

VENTURI SCRUBBER OPERATION

Proper operation of the scrubber also requires that the operator be able to correct problems when the key operating parameters fall outside acceptable ranges.

- Pressure drop across the venturi throat can be increased by adjusting the fan damper, increasing fan energy, or by adjusting the throat constriction on a variable-throat venturi scrubber.
- Liquid supply can be increased by increasing the liquid flow rate.
- If suspended solids cause solids buildup problems, the makeup water and blowdown rates should be increased.

VENTURI SCRUBBER STARTUP

Startup of a venturi scrubber requires adherence to the following in-sequence steps:

- Turn on the liquid recirculation system and liquid flow to the venturi throat and the mist eliminator;
- Adjust the liquid flow rates to those specified by the manufacturer;
- If the fan is equipped with a damper, close the damper;
- Start the fan;
- Gradually open the damper until the proper gas flow rate is established;
- Recheck the liquid flow rate, compare with the gas flow rate, and adjust as necessary to obtain the proper liquid supply;
- Check the scrubber pressure drop and adjust the fan energy or fan damper as necessary to obtain the desired pressure drop; and
- Initiate the liquid blowdown to treatment or disposal, as specified by the manufacturer.

VENTURI SCRUBBER SHUTDOWN

To shut a venturi scrubber system down, the following procedures should be adhered to in sequence:

- Shut off the scrubber fan;
- Wait until the fan impeller has stopped turning and shut off the scrubber water recirculation pump; and
- Shut off the makeup water supply system.

PACKED-BED SCRUBBER

KEY OPERATING PARAMETERS

The key operating parameters for a packed-bed scrubber are liquid supply, pH, suspended solids content, and inlet gas temperature.

RECOMMENDED OPERATING RANGES FOR KEY PARAMETERS

Because packed-bed scrubbers are usually used on hospital incinerators primarily for acid gas control, pH maintenance is important. High suspended solids levels can cause the same pluggage problems as for venturi scrubbers. Packed-bed units do not have high pressure drop requirements to enhance scrubbing; instead, they rely on high liquid supply rates and increased surface area for absorption. High inlet gas temperature can damage plastic packing media.

- The recommended range for liquid supply is 10 to 15 gal/1,000 acf (1.3 to 2.0 ℓ/m^3).
- The recommended range of pH is 5.5 to 7.0.
- The recommended range for suspended solids is 1 to 3 percent.
- Acceptable inlet gas temperatures are dependent on the packing media and scrubber material of construction and should be specified by the manufacturer.

MONITORING OF KEY PARAMETERS

Monitoring of liquid supply and suspended solids for packed-bed scrubbers are the same as discussed above for venturi scrubbers.

- Liquid feed pH usually can be monitored directly from a manufacturer-installed pH meter.
- A thermocouple usually is provided to monitor the gas inlet temperature.

PACKED-BED SCRUBBER OPERATION

Operation of packed-bed scrubbers with respect to liquid supply and suspended solids is the same as that for venturi scrubbers.

- The liquid feed pH can be increased by increasing the alkaline sorbent material feed rate to the scrubber water.
- Gas inlet temperatures can be controlled by controlling the flue gas exhaust temperatures from the incinerator or by adjusting an ambient air damper upstream of the scrubber.

PACKED-BED SCRUBBER STARTUP AND SHUTDOWN

Startup and shutdown procedures for packed-bed scrubbers are the same as those indicated above for venturi scrubbers.

FABRIC FILTERS

KEY OPERATING PARAMETERS

The key operating parameters for pulse-jet fabric filters are the maximum and minimum flue gas temperatures, the pressure drop through the unit, and the cleaning air pressure.

RECOMMENDED OPERATING RANGES FOR KEY PARAMETERS

Proper operation of a pulse-jet fabric filter requires that flue gas temperatures do not get high enough to damage the bags or low enough to allow condensation of moisture or acid gases to blind or corrode the bags. The bags should be cleaned on a frequency that will prevent excessive pressure drops that could result in ruptured bags and excessive fan energy costs. The cleaning air pressure should be high enough to ensure a shock wave in the bag sufficient to dislodge the filter cake.

- The maximum flue gas temperature is dependent on the bag material and should be specified by the manufacturer.
- The minimum gas temperature is dependent on the moisture content and acid gas content of the gas stream and should be maintained above the dewpoints of both. In practice, the fabric filter vendor or hospital engineer should specify a minimum flue gas temperature.
- The recommended pressure drop range for a pulse-jet fabric filter is 5 to 9 in. w.c. (1.2 to 2.2 kPa).
- The recommended range for the cleaning air pressure is 60 to 100 psig (410 to 690 kPa).

MONITORING OF KEY PARAMETERS

To ensure proper operation of a fabric filter, the operator should ensure that all bags are intact, without holes or tears, and that the bags are cleaned on an appropriate frequency with adequate cleaning air pressure. The integrity of the bags should be checked by a visual inspection when the system is off-line for routine maintenance.

- Parameters that can be monitored to maintain optimum fabric filter performance are:
  - -- opacity;
  - -- pressure drop; and
  - -- temperature.
- Opacity readings are taken at the stack by a trained observer or from an opacity monitor. Visible emissions of greater than 5 percent opacity may indicate holes in the bags or too frequent cleaning. If high opacities are observed, the bags should be inspected visually by maintenance personnel.
- A manometer or pressure gauge is usually provided by the manufacturer for measuring pressure drop. Excessively high pressure drop can indicate:
  - -- inadequate cleaning;
  - -- bag blinding; or
  - -- excessive gas volume.
- Fabric filters on hospital incinerators should be equipped with continuous stripchart temperature recorders and high temperature alarms. The stripchart recorder will indicate whether potential bag damage may have occurred due to high temperature. The alarm should be set lower than the critical bag damage temperature to

allow for preventive actions. The alarm temperature setting depends on the type of bag fabric used. These same devices can be used to monitor against excessively low temperature.

FABRIC FILTER OPERATION

Under normal conditions, the operator only has to monitor the key parameters and ensure that the airflow rate through the fabric filter is sufficient to maintain negative draft in the combustion chamber of the incinerator.

- If the flue gas temperature approaches the damage point, emergency procedures should be taken to reduce the temperature by:
  - bypassing the fabric filter;
  - dropping the incinerator temperature by increasing combustion airflow in the secondary chamber or reducing auxiliary fuel rates; or
  - introducing cooling ambient air.
- If the dewpoint temperature is approached, the incinerator secondary chamber burner firing rates should be increased to raise the inlet temperature.
- If the pressure drop is too high, the bag cleaning frequency should be increased.
- If the cleaning air pressure is too low, adjust the pressure gauge on the compressed air system.

FABRIC FILTER STARTUP

Precautions should be taken during initial startup of a new fabric filter or after bag replacement to prevent abrasion damage to the new bags before a protective coating of dust has formed. Condensation of moisture and acid gases should be prevented at all startups to prevent acid attack and bag "blinding."

- New bag abrasion can be prevented by:
  - operation of the incinerator at reduced throughput of waste charge material to allow the gradual buildup of the dust cake; and
  - precoating the bags
- Condensation of acid gases and moisture in a cold fabric filter can be prevented by operating the incinerator on auxiliary fuel prior to charging with waste until the fabric filter is heated.

FABRIC FILTER SHUTDOWN

The top priority during shutdown of a fabric filter is to avoid dewpoint conditions with resulting condensation.

- The incinerator secondary chamber burner should be left on for a few minutes after waste combustion is completed to remove moisture from the fabric filter.

- After the secondary chamber burner is shut down, ambient air should be drawn through the system to purge remaining combustion products.
- After combustion products are purged, the fabric filter should be allowed to go through 5 to 20 minutes of bag cleaning to remove the filter cake that could cause blinding if condensation occurs later in the unit after shutdown.

DRY SCRUBBERS - GENERAL

DRY SCRUBBER OPERATION

The basic operating principle for both spray dryers and dry injection is to mix an adequate supply of alkaline sorbent with the flue gas and allow sufficient contact time for the reaction to occur. On most units, outlet gas stream acid gas monitors will provide a direct indication of system performance.

SPRAY DRYERS

KEY OPERATING PARAMETERS

The key operating parameters that are necessary for effective operation of a spray dryer are sorbent feed, the slurry sorbent content, and the outlet gas wet and dry bulb temperatures. The wet bulb/dry bulb temperature readings give an indication of the saturation of the gas stream and the potential for evaporation of moisture.

RECOMMENDED OPERATING RANGES FOR KEY PARAMETERS

Effective operation of a spray dryer requires adequate sorbent for reacting with the acid gases and prevention of solids buildup. Solids buildup can occur if slurry moisture is not evaporated within the design time period. The liquid slurry feed rate and sorbent content should be balanced with the hot flue gas volume and acid gas content to ensure the desired removal of acid gases and evaporation of all moisture.

- The recommended range of slurry sorbent content is 5 to 20 percent solids by weight.
- A wet bulb/dry bulb outlet gas temperature difference of 90° to 180°F (30° to 80°C) will ensure evaporation of all moisture.

MONITORING OF KEY PARAMETERS

The sorbent content of the slurry does not require continuous monitoring. The sorbent content is set at the slurry mix tank. The outlet wet bulb and dry bulb temperatures are indicated by manufacturer-installed gauges.

SPRAY DRYER OPERATION

The feed rate of dry sorbent to the makeup water in the sorbent mix tank is adjusted to obtain the desired sorbent content of the slurry. The flow rate of slurry to the atomizer in the reaction vessel is adjusted to change the wet bulb/dry bulb temperature difference.

- The slurry flow rate is usually monitored by a magnetic flow meter.
- An increase in slurry flow will reduce the wet bulb/dry bulb temperature difference.

SPRAY DRYER STARTUP

Startup of a spray dryer should follow procedures that prevent condensation in the system and ensure evaporation of all slurry moisture in the scrubber reactor vessel.

- One method of ensuring evaporation is to use auxiliary fuel firing to bring the exhaust gas temperature up to the normal operating range before injecting the slurry.
- Another method would be to gradually increase slurry feed at startup to maintain a 90° to 180°F (30° to 80°C) wet bulb/dry bulb temperature differential.

SPRAY DRYER SHUTDOWN

Proper shutdown should ensure that no liquid moisture remains or condenses in the spray dryer or fabric filter after shutdown.

- Auxiliary fuel firing should be used to maintain temperatures above saturation until all sorbent is purged from the system.
- To prevent bag blinding and reaction product salt corrosion, the fabric filter should go through a complete cleaning cycle before shutdown.

DRY INJECTION

KEY OPERATION PARAMETERS

The key operating parameters for a dry injection system are the sorbent injection rate and the particle size of the sorbent.

- The sorbent injection rate should provide adequate sorbent for neutralization of the acid gases and is dependent on the acid gas content of the flue gas.
- As particle size decreases, the surface area to volume ratio increases which improves the efficiency of acid gas collection.

RECOMMENDED OPERATING RANGES FOR KEY PARAMETERS

The particle size and injection rate of the sorbent should be specified by the manufacturer.

- Generally the sorbent feed will have a particle size where 90 percent by weight will pass through a 325 mesh screen. This dust is approximately the consistency of talcum powder.

MONITORING OF KEY PARAMETERS

Continuous monitors for outlet acid gas concentrations are usually provided with dry scrubbing systems.

- The sorbent feed rate can be determined directly from manufacturer installed gauges.
- Proper particle sizes for the sorbent are specified at purchase and are maintained by transporting and fluidizing the sorbent through a positive pressure pneumatic conveyor. The air flow rate in the pneumatic line is set at a constant level and is not varied with the load.

DRY INJECTION OPERATION

Operation of a dry injection system is relatively simple.

- Maintain the pneumatic transfer line at a constant airflow rate.
- Monitor outlet acid gas concentration and increase sorbent injection rate to achieve desired acid gas levels.

DRY INJECTION STARTUP

There are no special startup considerations for dry injection. At startup of the incinerator, the dry sorbent can be injected without any special preparations.

DRY INJECTION SHUTDOWN

The only special concern for shutdown of a dry injection system is to put the fabric filter through a cleaning cycle after sorbent injection is stopped. This prevents possible blinding from condensation and reaction product salt damage to the fabric filter components.

ELECTROSTATIC PRECIPITATORS

KEY OPERATING PARAMETERS

The key operating parameters that are necessary for effective operation of an ESP are gas temperature, particulate resistivity, and power input.

RECOMMENDED OPERATING RANGES FOR KEY PARAMETERS

Proper operation of an ESP requires that the gas temperature, particulate resistivity, and power input be maintained within acceptable ranges as specified by the manufacturer or by the air agency permit specifications. Recommended ranges for these parameters are:

- Gas temperature range:
  - -- Hot-side ESP, 572° to 800°F (300° to 430°C)
  - -- Cold-side ESP, less than 400°F (200°C)
- Particulate resistivity range is 10^7 to 10^{10} ohm-cm
- Power ratio of secondary power to the primary power input should range from 0.5 to 0.9
  - -- secondary power = secondary voltage x secondary amperage
  - -- primary power = primary voltage x primary amperage

MONITORING OF KEY PARAMETERS

To ensure proper operation of an ESP, the operator must monitor the key parameters and make adjustments as necessary to maintain the parameters in the appropriate range.

- ESP parameters that can be monitored by the operator include:
  - -- gas inlet temperature
  - -- particulate resistivity
  - -- primary voltage
  - -- primary current
  - -- secondary voltage
  - -- secondary current
- The gas inlet temperature can be measured using a thermocouple mounted at the inlet to the ESP. A temperature readout such as a stripchart recorder or LED display should be available. Temperatures should be maintained above the dewpoints of both hydrochloric acid and moisture. Temperatures that are too low allow moisture and acid to condense causing sticky particulate that is difficult to collect and causing corrosion. Temperatures that are too high may cause damage to the ESP and in hot-side ESP's may cause the gas density to be so low that effective collection is difficult.
- Particulate resistivity is a measure of the resistance of the collected dust layer to the flow of electrical current. A high resistivity indicates that little electricity will flow. The condition of high resistivity is indicated by increased sparkover or by excessive current at greatly lowered voltages. Low resistivity (i.e., high electricity flow) means that particles lose their charge too quickly. Particles take longer to move to the collection plate, the particles are not held strongly to the collection plate, and particle reentrainment is a problem. Resistivity is measured using high voltage conductivity cells - the accepted method is the point-plane method.
- The transformer-rectifier (TR) power equipment of most modern ESP's are equipped with primary voltage and current meters on the

low-voltage (ac) side of the transformer and secondary voltage and current meters on the high-voltage rectified (dc) side of the transformer. Therefore, the input side is the primary side of the transformer. The primary meters measure voltage and current in volts and amps, respectively. The secondary meters measure voltage in kilovolts (volts multiplied by 1,000) and current in milliamps (amps divided by 1,000). To get the power ratio: (1) multiply the primary voltage reading by the primary current reading to get primary power, (2) multiply the secondary voltage reading by the secondary current reading to get the secondary power, and (3) divide the secondary power by the primary power level to get the power ratio.

ESP OPERATION

Under normal conditions, the operator need only monitor the key operating parameters and ensure that the airflow rate through the ESP is sufficient to maintain negative draft in the combustion chamber of the incinerator.

- If the dewpoint temperature is approached, the incinerator secondary chamber burner firing rates should be increased to raise the inlet temperature.
- If the flue gas temperature is too high, the temperature should be reduced by:
  - -- dropping the incinerator temperature
  - -- introducing cooling ambient air.
- If the resistivity is too high (i.e., increased sparking and/or excessive currents at greatly lowered voltages), it can be reduced by:
  - -- introducing cooling ambient air to reduce the gas temperature
  - -- adding moisture to the gas stream to both cool the gas and to enhance the conductivity of the particulate in the gas stream.
- If the resistivity is too low (i.e., increased particle reentrainment, poor collection efficiency), it can be increased by:
  - -- increasing the temperature of the gas by increasing the incinerator secondary chamber burner firing rates
  - -- checking operation of rappers
  - -- investigating incinerator feed characteristics for high-sulfur content or for excessive conditioning agents such as alkalis
  - -- improving incinerator combustion efficiency to reduce amount of carbon in collected dust.
- If the primary voltage is too low, it can be corrected by:
  - -- removing excessive ash from electrodes
  - -- checking power supply
  - -- checking for improper rectifier and control operation
  - -- checking for misaligned electrodes
  - -- checking for high resistivity.

ESP STARTUP

Startup of an ESP is generally a routine operation involving heating a number of components such as support insulators and hoppers prior to incinerator operation. The following steps should be taken to startup the incinerator.

Prior to operation of the incinerator:

- Check hoppers
  - level-indicating system should be operational
  - ash-handling system operating and sequence check - leave in operational mode
  - hopper heaters should be on
- Check rappers
  - energize control, run rapid sequence, ensure that all rappers are operational
  - set cycle time and intensity adjustments, using installed instrumentation - leave rappers operating
- Check TR sets
  - test-energize all TR sets and check local control alarm functions
  - set power levels and deenergize all TR controls
  - lamp and function-test all local and remote alarms

After the incinerator has gone through its preheat mode:

- Energize TR sets, starting with inlet field, setting Powertrac voltage to a point just below sparking.
- Successively energize successive field as load picks up to maintain opacity, keeping voltage below normal sparking (less than 10 flashes/min on spark indicator).
- Within 2 hours, check proper operation of collected dust removal system.
- After flue gas at 200°F (93°C) has entered ESP for 2 hours, perform the following steps:
  - check all alarm functions in local and remote
  - deenergize bushing heaters after 2 hours.
- Set normal rapping.

ESP SHUTDOWN

When charging has stopped and the incinerator goes into burndown mode, shut the ESP down by doing the following:

- Deenergize ESP by field, starting with inlet field to maintain opacity limit
- Deenergize outlet field when all fuel flow ceases and combustion airflow falls below 30 percent of rated flow.
- Leave rappers, ash removal system, seal-air system, and hopper heaters operational.

- Four hours after incinerator shutdown, deenergize seal-air system and hopper heaters. Secure ash removal system.
- Eight hours after incinerator shutdown, deenergize rappers.

  Note: Normal shutdown is a convenient time to check operation of alarms.

REVIEW EXERCISE

1. What is the recommended range for liquid supply to a venturi scrubber? a. 1-3 gal/1,000 acf b. 4-6 gal/1,000 acf c. 7-10 gal/1,000 acf d. 12-15 gal/1,000 acf	
2. What is the recommended range for suspended solids in a venturi scrubber? a. 0-3 percent b. 4-6 percent c. 7-10 percent d. 10-15 percent	1. c. 7-10 gal/ 1,000 acf
3. How can the pressure drop of a venturi scrubber be increased? a. Adjusting the fan damper b. Increasing fan energy c. Adjusting throat constriction d. All of the above	2. a. 0 to 3 percent
4. What is the recommended range for liquid supply to a packed-bed scrubber? a. 3-5 gal/1,000 acf b. 5-10 gal/1,000 acf c. 10-15 gal/1,000 acf d. 15-25 gal/1,000 acf	3. d. All of the above.
5. What is the recommended pH for a packed-bed scrubber? a. 2-3 b. 3-5.5 c. 5.5-7.0 d. 7.0-9.0	4. c. 10 to 15 gal/ 1,000 acf
6. What is the recommended pressure drop range for a pulse-jet fabric filter? a. 1-5 in. w.c. b. 5-9 in. w.c. c. 10-15 in. w.c. d. 15-20 in. w.c.	5. c. 5.5 to 7.0

REVIEW EXERCISE (CONTINUED)

7. Excessively high pressure drop in a fabric filter may indicate what? a. Inadequate cleaning b. Bag blinding c. Excessive gas volume d. All of the above	6. b. 5 to 9 in. w.c.
8. What is the recommended wet bulb/dry bulb temperature difference for a spray dryer? a. 10° to 25°F b. 25° to 50°F c. 50° to 75° F d. 90° to 180°F	7. d. All of the above.
	8. d. 90° to 180°F

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SESSION 8.
MAINTENANCE INSPECTION--A NECESSARY PART OF YOUR JOB

SESSION 8. MAINTENANCE INSPECTION--A NECESSARY PART OF YOUR JOB

TABLE OF CONTENTS

Page

INTRODUCTION.. 8-1

INCINERATOR MAINTENANCE INSPECTIONS.. 8-2

- Hourly Inspections.. 8-2
- Daily Inspections.. 8-2
- Weekly/Biweekly/Monthly Inspections.. 8-4

WET SCRUBBER MAINTENANCE INSPECTIONS.. 8-4

- Daily Inspections.. 8-4
- Other Inspections.. 8-6

FABRIC FILTER MAINTENANCE INSPECTIONS.. 8-6

- Daily Inspections.. 8-6

RECORDKEEPING.. 8-8

REFERENCES.. 8-12

LIST OF TABLES

TABLE 8-1. TYPICAL MAINTENANCE INSPECTION SCHEDULE FOR A HOSPITAL WASTE INCINERATOR.. 8-3

TABLE 8-2. TYPICAL MAINTENANCE INSPECTION SCHEDULE FOR A VENTURI SCRUBBER.. 8-5

TABLE 8-3. TYPICAL MAINTENANCE INSPECTION SCHEDULE FOR A FABRIC FILTER SYSTEM.. 8-7

TABLE 8-4. DAILY MAINTENANCE INSPECTION LOG.. 8-9

SESSION 8.
MAINTENANCE INSPECTION--A NECESSARY PART OF YOUR JOB

SESSION GOAL AND OBJECTIVES

GOAL

To familiarize you with:

- The hourly, daily, and weekly maintenance inspections that you should make on your hospital incinerator and air pollution control device;
- Maintenance problems that should be reported to the maintenance department; and
- Recordkeeping systems.

OBJECTIVES

Upon completing this session, you should be able to:

1. List the maintenance inspections that should be made on an hourly basis;
2. List the maintenance inspections that should be made on a daily basis;
3. List the maintenance inspections that should be made on a weekly basis;
4. Identify and alert maintenance personnel of potential problems; and
5. Implement a recordkeeping system.

INTRODUCTION

Typically, you will not perform preventive maintenance activities such as lubricating of moving parts, replacing parts, and repairing equipment. This preventive maintenance work is usually done by the maintenance department. Your responsibility concerning maintenance is to inspect the different parts of the incinerator and air pollution control device on a regular basis. In this way, you will be able to detect minor problems and report them to the maintenance department before they develop into large, expensive repairs and result in improper operation and increased air emissions. Therefore, this session describes the types of inspections that should be made by the operator and the potential problems that should be reported to the hospital's maintenance department. The following sections describe the maintenance inspections that should be observed on incinerators, wet scrubbers, and fabric filters. Recordkeeping or maintaining an activities logbook also is discussed.

INCINERATOR MAINTENANCE INSPECTIONS

The incinerator maintenance inspections that you should perform are listed in Table 8-1. The following sections describe these inspections in detail.

HOURLY INSPECTIONS

The hourly incinerator inspections apply only to large incinerators with automatic ash removal conveyors. On these systems, the following inspections should be made every hour:

- The ash removal conveyor should be inspected to clear away any debris that might cause it to jam; and
- The quench pit water level should be checked and water added if necessary--water must be available to quench the ash and to maintain the air seal that the water provides on the ash removal conveyor.

DAILY INSPECTIONS

On a daily basis, stack gas monitors (if your incinerator is equipped with one) should be checked for proper operation and various pieces of equipment should be inspected and cleaned as required. The following inspections should be made daily:

- If your incinerator is equipped with stack gas monitors, make daily calibration checks on opacity monitor and check readings on oxygen, carbon monoxide or hydrogen chloride monitors--anything out of the ordinary such as unusually low or high readings should be reported to the maintenance department;
- Observe the exhaust stack for visible emissions and compare to the opacity monitor reading--you should make these exhaust stack observations several times a day especially after waste charging and during the burndown mode;
- Check thermocouple temperature readings--anything out of the ordinary such as slow response time or unusually low or high temperature readings should be reported to the maintenance department;
- On batch incinerators and prior to operation, inspect the charge door seals for closeness of fit and wear by closing the charge door and looking for any gaps in the door seal material--any gaps should be reported to the maintenance department;
- Inspect limit switches for freedom of operation and remove any obstructing debris; and
- On controlled-air incinerators, inspect and clean underfire air ports--on batch units, cleaning is best accomplished by rodding the air ports after the previous shift's ash has been removed--large, continuous feed units usually have cleaning mechanisms that may be used to rod out the air ports while the unit is in operation. [Note that multiple-chamber incinerators (i.e. excess-air units) are supplied with air through overfire air ports that are unlikely to become plugged.]

TABLE 8-1. TYPICAL MAINTENANCE INSPECTION SCHEDULE FOR A HOSPITAL WASTE INCINERATOR

Activity frequency	Incinerator component	Procedure
Hourly	Ash removal conveyor	Inspect and clean as required
	Water quench pit	Inspect water level and fill as required
Daily	Opacity monitor	Check readings; check daily calibration values
	Stack	Check exhaust for visible emissions
	Oxygen monitor	Check oxygen level of exhaust
	Thermocouples	Check temperature readings
	Limit switches	Inspect for freedom of operation and potential obstructing debris
	Underfire air ports	Inspect and rod out
Weekly	Blower intakes	Inspect for accumulations of lint, debris and clean as required
	Induced-draft fans	Inspect and clean fan housing as required. Check for corrosion and V-belt drives and chains for tension and wear.
Biweekly	Control panels	Inspect and clean as required. Keep panel securely closed and free of dirt to prevent electrical malfunction
Monthly	External surface of incinerator and stack	Inspect external "hot" surfaces. White spots or discoloration may indicate loss of refractory

WEEKLY/BIWEEKLY/MONTHLY INSPECTIONS

Every week, all blower intakes and induced-draft (ID) fans used for heat recovery should be inspected for dirt accumulation and cleaned as required. Also, the ID fans used for heat recovery should be inspected for corrosion, and V-belt drives and chains should be checked to make sure they are not frayed or loose. Any corrosion or wear and any loose or frayed V-belts or chains should be reported to the maintenance department.

Every 2 weeks, the incinerator's control panel should be inspected for dirt accumulation and cleaned as required. The panel door should be kept closed to prevent dirt accumulation and electrical malfunction.

Every month, you should inspect the outer surface of the incinerator and the refractory lining inside. Any discoloration or white "hot" spots on the outer surface may indicate a loss of refractory inside the unit and should be reported to the maintenance department. These white spots are usually the first indication of internal refractory damage. When the refractory lining is cold, random cracks may be seen that vary in width from 1/32 to 3/16 inch (0.01 to 0.07 centimeter). These cracks are normal and close up when the refractory expands at operating temperatures. The purpose of inspecting the cold refractory each month is to observe any changes in existing cracks and to discover any holes larger than the cracks. These inspections are very important because replacing badly damaged refractory is very expensive. However, minor damage caught early enough may be repaired by the maintenance department using plastic refractory material.

WET SCRUBBER MAINTENANCE INSPECTIONS

The wet scrubber maintenance inspections that you should perform are listed in Table 8-2. The following section describes these inspections in detail.

DAILY INSPECTIONS

The following inspections should be made on a daily basis:

- Inspect the following equipment for leakage by looking for scrubber liquid escaping from the components and for any liquid on surfaces directly under the equipment. All leaking components should be reported to the maintenance department for repair.
  - -- scrubber liquid pump
  - -- variable throat activator
  - -- scrubber liquid lines
  - -- mist eliminator pressure lines
  - -- reagent feed system
- Inspect the scrubber liquid pump for proper operation by noting the flowmeter reading--lower flow rates than normal may indicate pump problems.
- On variable throat venturi scrubbers, inspect the variable throat activator for proper operation by moving the activator and checking the resulting pressure drop--the activator should move

TABLE 8-2. TYPICAL MAINTENANCE INSPECTION SCHEDULE FOR A VENTURI SCRUBBER

Inspection frequency	Component	Procedure
Daily	Scrubber liquid pump	Check for proper operation and leakage
	Variable throat activator	Check for proper operation and leakage
	Scrubber liquid lines	Check for leakage
	Mist eliminator pressure lines	Check for leakage
	Reagent feed system	Check for leakage
	Fan	Check for vibration and proper operation
	Fan belt[a]	Check for abnormal noise or vibration
Monthly	Duct work	Inspect for leakage

[a] Check fan belt tension whenever fan is out of service.

freely and the pressure drop should increase as the activator is moved upwards to constrict the venturi throat.

- Inspect the scrubber fan and fan belt for any abnormal vibration or noise--any abnormal vibration or noise indicates that the fan should be serviced by the maintenance department.

OTHER INSPECTIONS

Every month, the off-gas ductwork should be checked for leakage, i.e., look for holes and listen for air being sucked in. Any problems should be reported to the maintenance department for repair.

All other maintenance activities will likely be performed by the maintenance department during regular shutdowns. Such activities include inspecting the internal scrubber components for corrosion, abrasion, and material buildup (monthly); lubricating scrubber components including fan and pump (weekly); inspecting fan, pump, motor, and drag chain bearings, and damper seals, bearings, blades and blowers for wear and loose fittings (semiannually); and checking the accuracy of flowrates (semiannually).

FABRIC FILTER MAINTENANCE INSPECTIONS

The fabric filter maintenance inspections that you should perform are listed in Table 8-3. The following section describes these inspections in detail.

DAILY INSPECTIONS

The following inspections should be made on a daily basis:

- Inspect the exhaust stack for visible emissions--a sudden change in opacity may indicate the failure of one or more system components including broken/leaking bags or a malfunctioning cleaning system--the appearance of puffing smoke indicates pinhole leaks in a filter bag(s);
- Check and record fabric pressure loss and fan static pressure--sudden changes in the pressure drop may indicate problems; i.e. high pressure drop may indicate mudded bags or cleaning system failure (listen to the system-does it sound different?) while low pressure drop may indicate fabric failure (holes);
- Check the compressed air system for air leakage by observing the system's pressure gauge--air leakage may be indicated by a lower pressure than normal;
- Check all indicators on the fabric filter control panel and listen to the system in operation--you should become familiar with the sounds that your system makes when operating normally ; and
- Inspect the dust removal system to see that dust is being removed from the system by checking the conveyor for jamming, pluggage, wear, broken parts, etc.--problems with the conveyor system are indicated when the conveyor appears to be moving but no dust is dropping into the dust storage container, when the conveyor does not move, or when the conveyor makes unusual sounds.

TABLE 8-3. TYPICAL MAINTENANCE INSPECTION SCHEDULE FOR A FABRIC FILTER SYSTEM

Inspection frequency	Component	Procedure
Daily	Stack	Check exhaust for visible dust.
	Manometer	Check and record fabric pressure loss and fan static pressure. Watch for trends.
	Compressed air system	Check for air leakage (low pressure). Check valves.
	Collector	Observe all indicators on control panel and listen to system for properly operating subsystems.
	Rotating equipment and drives	Check for signs of jamming, leakage, broken parts, wear, etc.
	Dust removal system	Check to ensure that dust is being removed from the system.
	Hoppers	Check for bridging or plugging by looking into the hopper with the system shut down.

If you encounter any of the indicators of deteriorating performance listed above, you should report the problem(s) to the maintenance department for repair.

RECORDKEEPING

Recordkeeping of maintenance inspections is an important part of an equipment operation and maintenance program. The objectives of recordkeeping are to prevent premature failure of equipment, increase equipment life, and minimize air pollution. These objectives can be achieved by observing trends in the frequency and types of maintenance required and by detecting problems early through regular maintenance inspections. Table 8-4 shows an example of a daily maintenance inspection log that you could use to record the dates and times when specific inspections are performed. A similar log can be set up for inspections that occur weekly or less frequently. You could set a log up for the incinerator and another for the air pollution control device.

TABLE 8-4. DAILY MAINTENANCE INSPECTION LOG

Facility name: ______________________________

Operator's name: ______________________________

Date: ______________________________

Time	Equipment inspected	Notes
	Ash removal conveyor	
	Water quench pit	
	Opacity monitor	
	Oxygen monitor	
	Underfire air ports	
	Ash pit/dropout sump	
	Stack	
	Scrubber liquid pump	
	Variable throat activator	
	Scrubber liquid lines	
	Mist eliminator pressure lines	
	Reagent feed system	
	Fan	
	Fan belt	

REVIEW EXERCISE

1. It is the operator's responsibility to _______ the different parts of the incinerator and air pollution control device on a regular basis.
2. Maintenance inspections allow you to identify minor problems before they develop into large, _________ repairs.
3. The ash removal conveyor should be inspected every hour to clean away any debris that might cause it to ____.
4. Daily calibration checks should be made on the ___________ monitor.
5. The exhaust stack should be checked for _______ emissions and compared to the opacity monitor reading.
6. Limit switches should be checked for freedom of operation and any obstructing _______ removed.
7. The underfire air ports should be inspected daily and cleaned (rodded) as necessary. True or False?
8. All blower intakes and induced draft (ID) fans should be inspected weekly for ____ accumulation and cleaned as required.
9. Any frayed or loose V-belt drives and chains or any corrosion found during inspection of ID fans should be reported to the __________ department.
10. White spots or discoloration of the outer surface of the incinerator found during the monthly inspection may indicate a ________ of refractory inside the unit and should be reported to the maintenance department.

1. inspect
2. expensive
3. jam
4. opacity
5. visible
6. debris
7. True
8. dirt
9. maintenance

(continued)

REVIEW EXERCISE (CONTINUED)

11. List three of the five scrubber components that should be inspected daily for fluid leakage.	10. loss
12. The fan, including bearings and belt, should be checked daily for any abnormal ______ or vibration.	11. Scrubber liquid pump Variable throat activator Scrubber liquid lines Mist eliminator pressure lines Reagent feed system
13. Every month, the scrubber off-gas ductwork should be checked for ______ and air being sucked in.	12. noise
14. When a baghouse is used, a sudden change in the ______ of the exhaust gas may indicate the failure of one or more system components including broken/leaking bags or a malfunctioning cleaning system.	13. holes
15. Changes in the pressure drop across the fabric filter indicate the failure of one or more system components. True or False?	14. opacity
16. You should inspect the fabric filter dust removal system to see that dust is being removed from the system by checking the conveyor for jamming, wear, broken parts. True or False?	15. True
	16. True

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SESSION 9.
TYPICAL PROBLEMS

SESSION 9. TYPICAL PROBLEMS

TABLE OF CONTENTS

Page

SESSION GOAL AND OBJECTIVES.. 9-2

INTRODUCTION... 9-2

INCINERATOR PROBLEMS... 9-3

PREVENTING PROBLEMS.. 9-9

WET SCRUBBER PROBLEMS.. 9-11

PREVENTING PROBLEMS.. 9-14

FABRIC FILTER PROBLEMS 9-16

PREVENTING PROBLEMS.. 9-17

REFERENCES... 9-18

LIST OF FIGURES

Figure 9-1. Black smoke leaving stack............................ 9-3

Figure 9-2. White smoke leaving stack............................ 9-4

Figure 9-3. White smoke/haze above the stack..................... 9-5

Figure 9-4. Smoke leaking from primary chamber................... 9-7

Figure 9-5. Excess auxiliary fuel usage.......................... 9-8

Figure 9-6. Incomplete burnout/poor ash quality.................. 9-10

Figure 9-7. Causes of high opacity emissions..................... 9-14

Figure 9-8. Causes of high pressure drop......................... 9-15

SESSION 9.
TYPICAL PROBLEMS

SESSION GOAL AND OBJECTIVES

GOAL

To familiarize you with the most frequent operational problems and how to prevent or correct them.

OBJECTIVES

Upon completing this session, you should be able to:

1. Identify the most frequent operational problems with incinerators and air pollution control systems;
2. Recognize the causes of operational problems; and
3. Describe the actions to take to correct and prevent operational problems.

INTRODUCTION

As an incinerator operator, you will experience problems periodically with the incinerator and air pollution control system. Many times, problems can be prevented if you are aware of how to keep them from happening. Sometimes, though, there are problems that you could not have prevented, and you need to know how to correct them as quickly as possible. Knowing how to prevent and correct operational problems will help you to do your job better and will also help to reduce air pollution from the incinerator. In this session, the most frequent operational problems are identified. These problems are numbered and listed below. The possible causes for each problem are discussed along with actions you can take to correct the problem.

You will also be given information on how to prevent the problem from happening in the future. An effective preventive maintenance program can reduce the number of problems by correcting malfunctions, making changes to prolong equipment life, and correcting minor problems before they require costly, time-consuming repairs.

INCINERATOR PROBLEMS

PROBLEM NO.	PROBLEM DESCRIPTION
1	Black smoke leaving stack
2	White smoke leaving stack

3	White smoke or haze appearing a short distance above the stack
4	Smoke leaking from primary chamber
5	Excessive auxiliary fuel usage
6	Incomplete burnout/poor ash quality

PROBLEM NO. 1 Black smoke leaving stack (see Figure 9-1)

CAUSE: Incomplete burning of waste

- Not enough air for good combustion
- Overcharging or charging highly volatile material
- Poor mixing in secondary chamber
- Burner failure
- Operating at too high a primary chamber temperature

SOLUTION/PREVENTION: Do the following, in order, to correct the problem:

- Check/increase secondary chamber combustion air
- Check/decrease primary chamber combustion air (underfire air or overfire air)
- Check secondary chamber temperature/assure above minimum level
- Decrease charge size or charge rate
- Check burner operation--if no flame or a poor flame is visible through the flame viewport, call maintenance to repair

PROBLEM NO. 2 Steady stream of white smoke leaving stack (see Figure 9-2)

PROBABLE CAUSE: Small aerosols in stack gas

- Too much air entering incinerator
- Secondary chamber temperature too low

SOLUTION/PREVENTION: Do the following, in order, to correct the problem:

- Be sure secondary burner is operating properly
- Be sure temperature of secondary chamber is above 1800°F (980°C)
- Check/decrease underfire air
- Check/decrease secondary chamber air
- If the above steps fail to eliminate white smoke, the feed material probably contains pigments, metallic oxides, or minerals (often found in paper sacks).

PROBLEM NO. 3 White smoke/haze appearing a short distance above stack (see Figure 9-3)

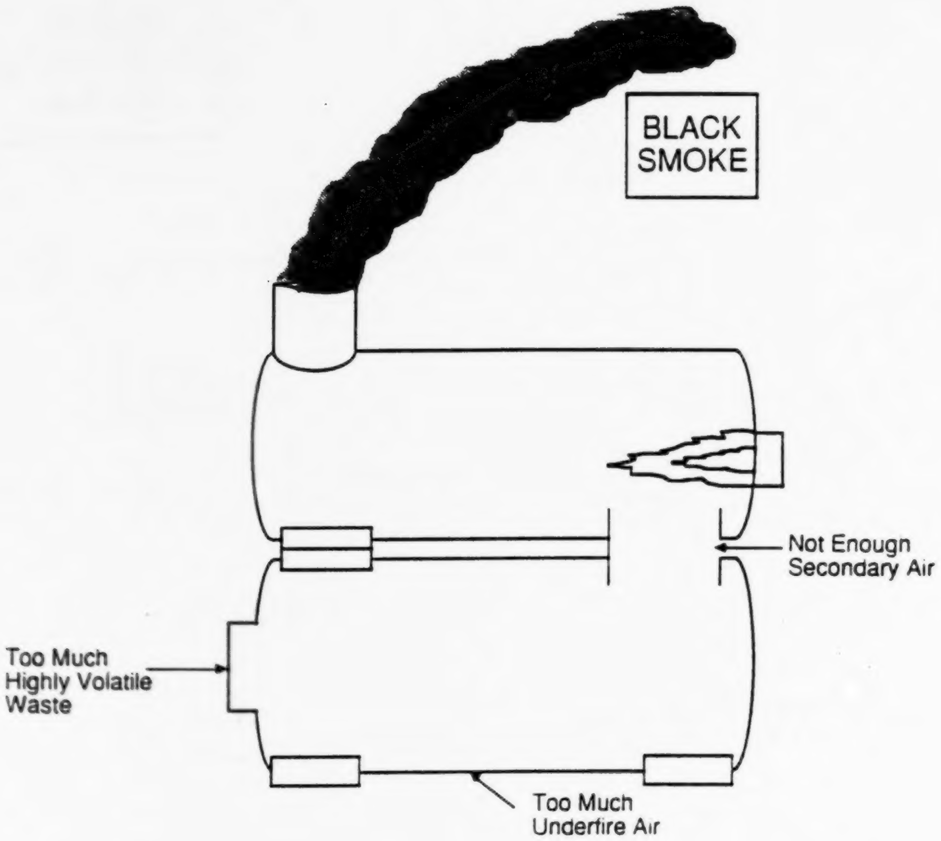
BLACK SMOKE
Not Enougn Secondary Air
Too Much Highly Volatile Waste
Too Much Underfire Air

Figure 9-1. Causes of black smoke.

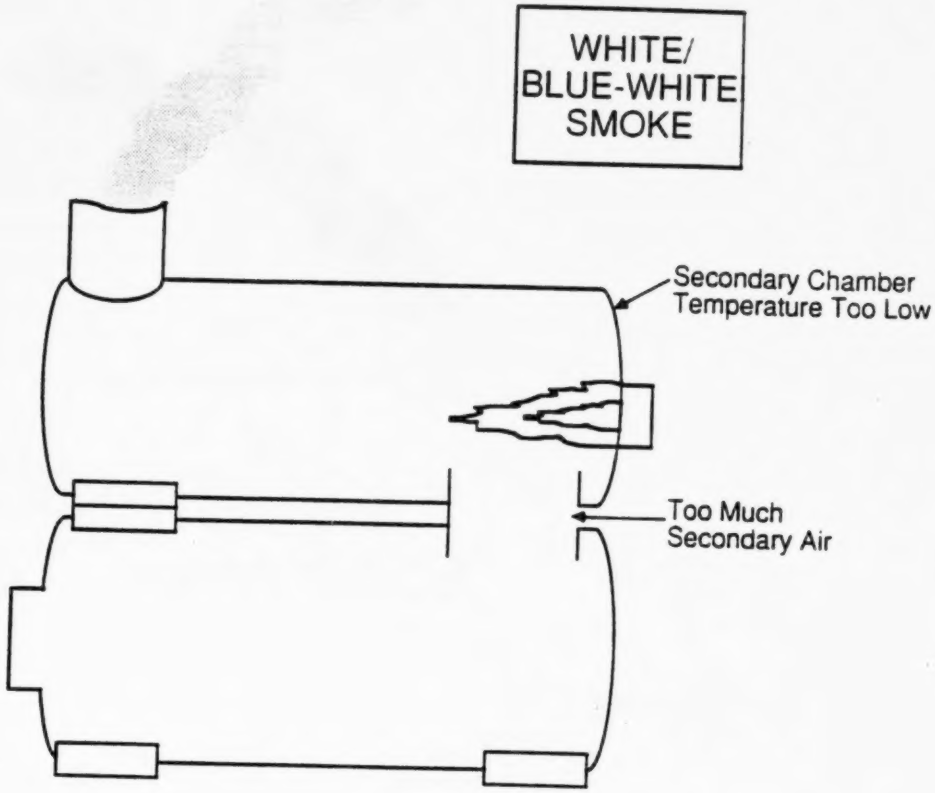
WHITE/
BLUE-WHITE
SMOKE
Secondary Chamber Temperature Too Low
Too Much Secondary Air

Figure 9-2. Causes of white smoke.

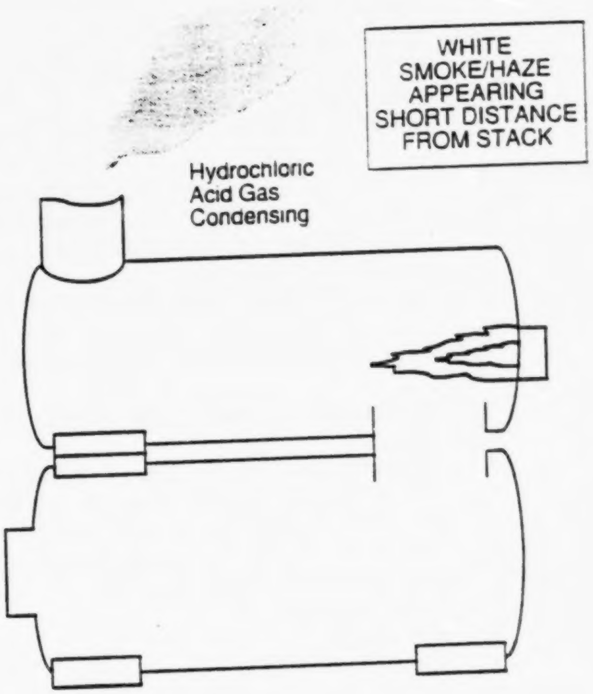
WHITE SMOKE/HAZE APPEARING SHORT DISTANCE FROM STACK
Hydrochloric Acid Gas Condensing

Figure 9-3. Cause of white plume a short distance above the stack.

PROBABLE CAUSE: Hydrochloric acid gas condensing

SOLUTION/PREVENTION: Not much you can do unless you can:

- Reduce amount of chlorinated waste incinerated in each load, or
- Eliminate chlorinated plastics from use in hospital, or
- Install acid gas scrubbing system

PROBLEM NO. 4 Smoke leaking from primary chamber (see Figure 9-4)

CAUSE: Positive pressure in primary chamber

- Too much underfire air
- Too much highly volatile material charged
- Problem with draft damper or induced draft fan (poor draft)
- Primary chamber temperature too high

SOLUTION/PREVENTION: Do the following, in order, to correct the problem:

- Check stack damper or fan operation
- Check/decrease underfire air
- Decrease feed rate
- Check charging door seals for leakage

PROBLEM NO. 5 Too much auxiliary fuel usage (see Figure 9-5)

CAUSE: Not enough heat input from waste to keep temperature high enough

- Inconsistent charging of incinerator
- Insufficient underfire air (starved-air units) or poor underfire air distribution
- Too much secondary combustion air
- Too much air infiltration
- Fuel leakage
- Wet waste
- Excessive draft
- Burner setting too high

SOLUTION/PREVENTION: Do the following to correct the problem:

- Charge waste at regularly timed intervals at a rate near 100 percent of incinerator capacity (Example: For 500 lb/h (230 kg/h) unit, charge 50 lb (23 kg) every 6 minutes)
- Spread wet waste with other waste through several charges--do not charge all of the wet waste at one time
- Check/increase underfire air (controlled-air unit); check air ports and distribution
- Check/reduce secondary combustion air
- Check/reduce draft
- Check charging door seals and other seals for air leakage

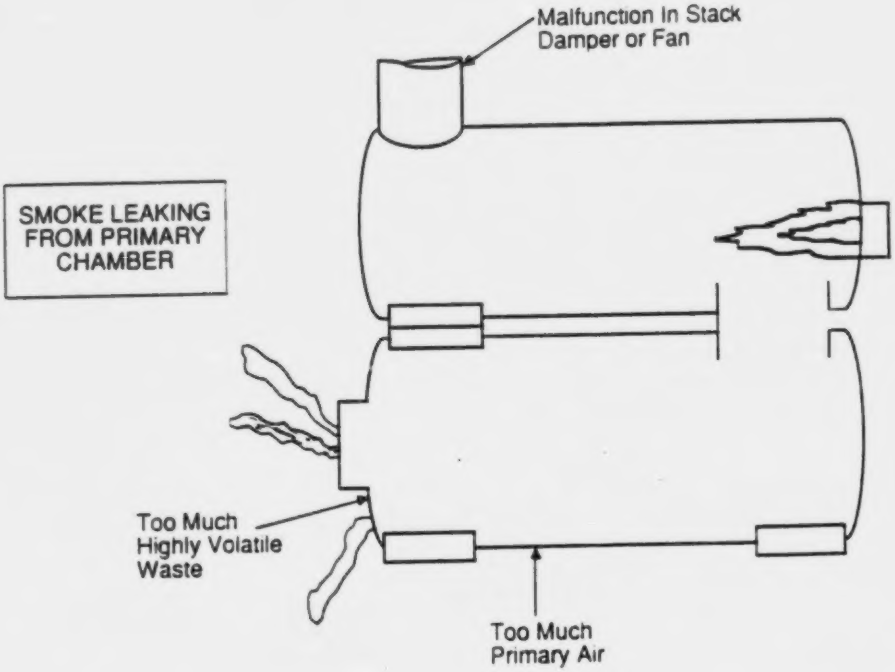
Malfunction In Stack Damper or Fan
SMOKE LEAKING FROM PRIMARY CHAMBER
Too Much Highly Volatile Waste
Too Much Primary Air

Figure 9-4. Causes of leaking smoke.

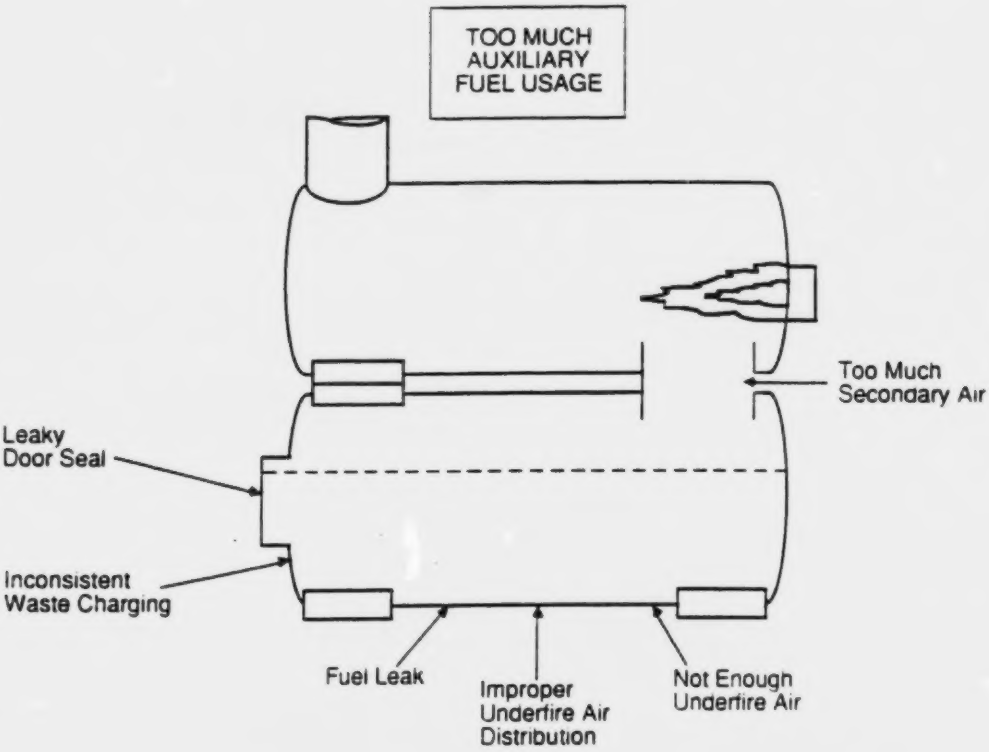
TOO MUCH AUXILIARY FUEL USAGE
Too Much Secondary Air
Leaky Door Seal
Inconsistent Waste Charging
Fuel Leak
Improper Underfire Air Distribution
Not Enough Underfire Air

Figure 9-5. Causes of excessive auxiliary fuel use.

- Check/decrease burner setting
- Check fuel trains and burners for fuel leakage

PROBLEM NO. 6 Incomplete burnout/poor ash quality (see Figure 9-6) (Three causes of this problem are detailed below.)

CAUSE NO. 1: Not enough underfire air or poor distribution

- Improper underfire air setting
- Clinker buildup around underfire air ports
- Air ports clogged with ash from previous charges
- Poor draft

SOLUTION/PREVENTION: Do the following to correct the problem:

- Check underfire air setting and adjust if needed
- Check around underfire air ports for clinker buildup and clean as needed
- Rod underfire air ports daily to remove clinker buildup and ash

CAUSE NO. 2: Improper waste charging

- Overstuffing incinerator
- Too much wet waste

SOLUTION/PREVENTION: Do the following to correct the problem:

- Charge waste at regularly timed intervals at a rate near 100 percent of incineration capacity (Example: For 500 lb/h [230 kg/h] unit, charge 50 lb [23 kg] every 6 minutes). Do not overstuff
- Spread wet waste through several charges--do not charge all of the wet waste at one time

CAUSE NO. 3: Insufficient burndown time

SOLUTION/PREVENTION: Do the following to correct the problem:

- Allow longer burndown period
- Use primary burner to maintain temperature during burndown period

PREVENTING PROBLEMS

It is better to prevent a problem than to have to correct a problem after it has occurred. A couple of actions you can take to prevent problems with your incinerator are noted below.

1. Properly charge the incinerator.

2. Note small maintenance problems and have them fixed before they become big problems, for example, sticking or squeaking dampers, loose control arms on dampers.

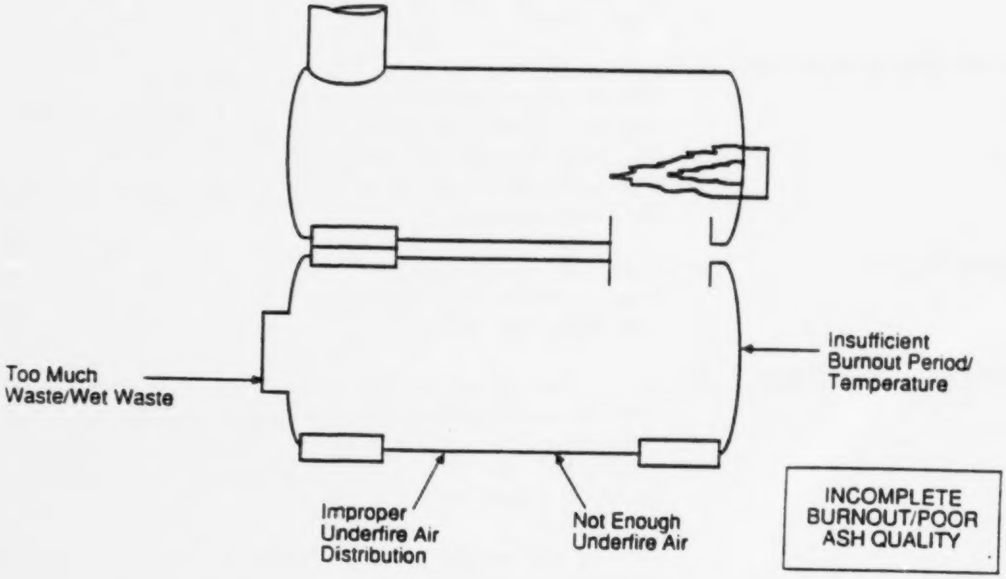
Too Much
Waste/Wet Waste
Insufficient
Burnout Period/
Temperature
Improper
Underfire Air
Distribution
Not Enough
Underfire Air
INCOMPLETE
BURNOUT/POOR
ASH QUALITY

Figure 9-6. Causes of incomplete burnout/poor ash quality.

WET SCRUBBER PROBLEMS

Wet scrubber problems are usually the result of corrosion, erosion, scaling, or plugging. Corrosion is a process where the scrubber internal components are worn away by the chemical action of the acid exhaust gas from a medical waste incinerator or by the alkaline scrubber liquor. Erosion is a process where the scrubber internal components are worn away by the abrasive action of the airborne particles in the incinerator exhaust gas. Scaling occurs when the particles in the incinerator exhaust gas begin to build up on the scrubber internal components such as fan blades. Plugging occurs mainly in scrubber spray nozzles when scrubber water containing captured particulate is recycled and the particulate builds up in and around the nozzle tip.

Typically, these problems will be invisible to the operator because they occur inside the scrubber. Most operational problems encountered by wet scrubbers can be prevented with a good preventive maintenance program. Steps that you can take to detect or prevent some of these problems are outlined below. However, call maintenance whenever a problem comes up. Here is a list of wet scrubber problems.

PROBLEM NO.	PROBLEM DESCRIPTION
7	Corrosion of scrubber parts
8	Fan vibration, dampers stuck, poor nozzle spray pattern
9	Erosion of dry service components
10	Erosion in wet service components

PROBLEM NO. 7	Corrosion of scrubber parts (scrubbers, absorbers, fans, dampers, ductwork, exhaust stack, pumps, valves, pipes, tanks, feed preparation equipment)
CAUSE:	Acid buildup in scrubbing liquid from absorption of sulfur dioxide, sulfur trioxide, and hydrogen chloride
SOLUTION/PREVENTION:	Maintain the pH of the scrubbing liquid by doing the following: • Check alkaline addition system for leaks daily and have the maintenance department repair if needed • Check pH monitor that controls alkaline additions daily • Have the maintenance department perform regular preventive maintenance on pumps, pipes, valves, tanks and feed preparation equipment in slurry service
PROBLEM NO. 8	Fan vibration, dampers stuck, poor nozzle spray pattern

CAUSE: Scaling/plugging

SOLUTION/PREVENTION: Preventive maintenance

- Periodic cleaning of equipment

PROBLEM NO. 9: Erosion in dry service components (fans, dampers, ductwork)

- Erosion of fan blades
- Holes in ductwork

CAUSE:

- Droplet carryover due to poor mist eliminator performance
- Normal operation

SOLUTION/PREVENTION: Preventive maintenance
Repair/replacement of equipment

PROBLEM NO. 10: Erosion in wet service components (scrubber and scrubber spray nozzles) (if recirculation is not practiced, then erosion in wet service will not be a problem)

CAUSE: Suspended solids in scrubbing liquid

- High recirculation flow rate compared to makeup and purge flow rates
- Infrequent purging of system

SOLUTION/PREVENTION: Preventive maintenance

- Purge system frequently to prevent solids buildup
- Adjust recirculation rate as needed

PREVENTING PROBLEMS

It is better to prevent a problem than to have to correct a problem after it has occurred. A few actions you can take to prevent problems with a wet scrubber are noted below.

1. Maintain proper pH for scrubber liquid.

2. If recirculation is used, maintain low level of solids in scrubbing liquid.

3. Establish preventive maintenance program to inspect and clean scrubber parts, including nozzles, fan, and dampers. (The Maintenance Department would be responsible for this action.)

FABRIC FILTER PROBLEMS

Problems with fabric filters are usually indicated by either unusually high or low pressure drop readings or by high opacity (greater than 5 percent) from the fabric filter stack. High pressure drop indicates a higher resistance to airflow meaning that the filter bags are not being cleaned properly or that they are mudded or blinded because of condensation of moisture. Low pressure drop and high opacity indicate a lower resistance to airflow due to holes in the filter bags (caused by abrasion, too frequent cleaning, or acid gas condensation) or improper bag installation (fallen bags, improperly sealed or tensioned bags). The causes of high opacity emissions and high pressure drop are shown in Figures 9-7 and 9-8, respectively. All high opacity and high or low pressure drop readings should be reported tc the maintenance department. Readings of these parameters recorded in a log book will allow you to see trends in readings that indicate a problem.

Acid gas and water condensation can be prevented by maintaining the temperature of both, the inlet gas to the fabric filter and the fabric filter itself above the dewpoints of water and the acid gas. Additionally, the inlet gas temperature must not be excessive such that damage to the filter bags or fire occurs. Some fabric filters are equipped with alarms and a bypass stack that diverts the gas if the temperature exceeds or falls below a certain limit. Filter bag abrasion may be eliminated by proper installation of the filter bags (done by the Maintenance Department, not you) assuming that the fabric filter has been properly designed. Finally, cleaning system failure (you'll know by no sound or different sounds) is best prevented by preventive maintenance on the part of the Maintenance Department.

PREVENTING PROBLEMS

It is better to prevent a problem than to have to correct a problem after it has occurred. A couple of actions you can take to prevent problems with a fabric filter are noted below.

1. Observe pressure drop readings. Any low or high readings indicates a problem and should be reported to the maintenance department.

2. Observe opacity. High opacity indicates fabric failure and should be reported to the maintenance department.

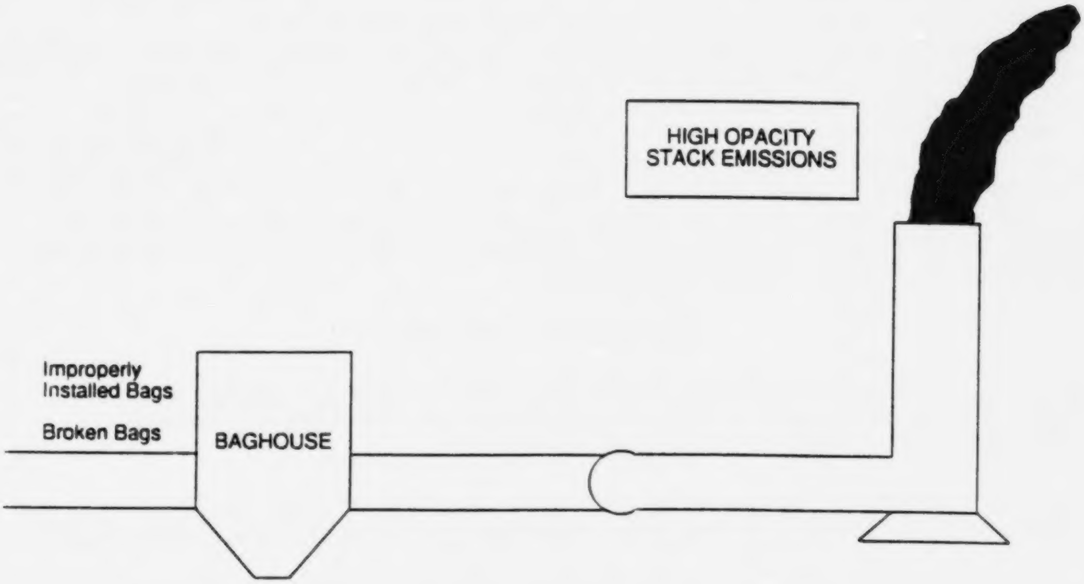
HIGH OPACITY
STACK EMISSIONS
Improperly
Installed Bags
Broken Bags
BAGHOUSE

Figure 9-7. Causes of high opacity emissions.

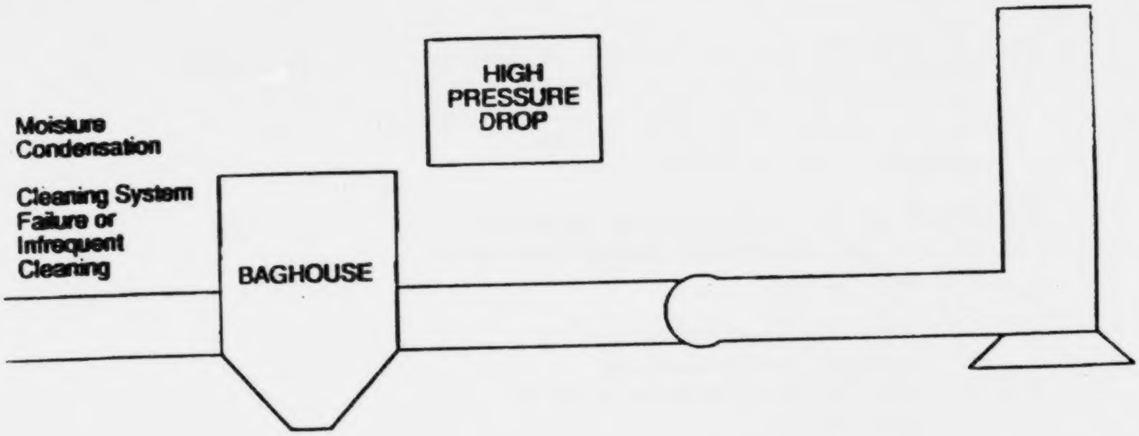
Moisture Condensation
Cleaning System Failure or Infrequent Cleaning
BAGHOUSE
HIGH PRESSURE DROP

Figure 9-8. Causes of high pressure drop across fabric filter.

REVIEW EXERCISE

1. Which of the following problems is probably caused by too much air entering the incinerator and insufficient temperature? a. Black smoke leaving stack b. White smoke leaving stack c. Poor ash quality d. Incomplete burnout	
2. Increasing the charging rate is a possible solution to the problem of black smoke leaving the stack. True or False?	1. b. White smoke leaving the stack
3. If smoke is leaking from the primary chamber, there may be either too much underfire air, poor draft, or too much highly volatile material in the charge. True or False.	2. False?
4. Which of the following are possible causes for incomplete burnout and poor ash quality. a. Not enough underfire air b. Improper waste charging c. Insufficient burndown time or temperature d. All of the above e. None of the above	3. True
5. Corrosion of parts of a wet scrubber is caused by: a. Too much iron in the water b. Acid buildup in the scrubbing liquid c. Both of the above d. Neither of the above	4. d. All of the above

(continued)

REVIEW EXERCISE (CONTINUED)

6. Problems such as plugging, stuck dampers, and fan vibration resulting from deposits on fan blades are caused by: a. Scaling b. Erosion c. Corrosion	5. b. Acid buildup in the scrubbing liquid
7. Erosion in the scrubber and scrubber spray nozzles can be reduced by which of the following? a. Rod out spray nozzles regularly b. Purge system frequently c. Adjust recirculation rate if needed d. All of the above e. b and c only	6. a. Scaling
8. When a fabric filter is operating normally, the opacity of stack emissions should be very low (less than 5 percent). True or False?	7. e. b and c only
9. Which of the following are possible causes of fabric failure resulting in high opacity? a. Improper installation of filter bags b. High temperature in the fabric filter baghouse c. Acid gas condensation on the filter bags d. Abrasion of the filter bags e. All of the above f. b, c, and d	8. True
10. High pressure drop indicates a high resistance to flow. True or False?	9. e. All of the above
	10. True

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SESSION 10.
STATE REGULATIONS

SESSION 10. STATE REGULATIONS

TABLE OF CONTENTS

Page

SESSION GOAL AND OBJECTIVES.................................... 10-2

INTRODUCTION... 10-2

THE AIR POLLUTANTS... 10-3

REGULATORY REQUIREMENTS.. 10-4

  Emission Limits.. 10-4
  Monitoring and Recordkeeping................................. 10-7
  Enforcement of State Regulations............................. 10-8
  Operator Training.. 10-8

YOUR STATE REGULATION.. 10-8

LIST OF FIGURES

Figure 10-1. Concentration standards........................... 10-3

Figure 10-2. Correction for dilution........................... 10-4

Figure 10-3. Exhaust gas monitors.............................. 10-6

SESSION 10.
STATE REGULATIONS

SESSION GOAL AND OBJECTIVES

GOAL

To familiarize you with major aspects of air pollution regulations that apply to your incinerator.

OBJECTIVES

Upon completing this session, you should be able to:

1. List the air pollutants from hospital waste incinerators that are likely to be regulated by your State;
2. Recognize the types of requirements that may be included in regulations; and
3. Describe how regulatory agencies determine whether your facility is complying with applicable regulations.

INTRODUCTION

Many State regulations include requirements to reduce air pollutant emissions from incineration of general hospital wastes and infectious wastes. Some or all of the requirements may be specified according to the size of the incinerator. For example, large incinerators may be required to meet stricter requirements for more pollutants than small incinerators, and very small incinerators may have few restrictions.

State regulations typically include the following types of requirements which are discussed in this session:

- Emission limits for air pollutants that leave the incinerator stack;
- Operating practices/limits;
- Continuous monitoring of emissions or other indicators of performance;
- Recordkeeping and reporting; and
- Operator training.

The requirements for your particular State will be summarized later. In addition to these requirements, your facility will have received a "permit" from the State and/or local Agency which may include specific requirements for your incinerator and air pollution control system that may be more strict than the general State regulations.

THE AIR POLLUTANTS

Listed below are the air pollutants from hospital waste incinerators that may be covered by emission limits in State regulations

Particulate matter;
Carbon monoxide;
Sulfur dioxide;
Nitrogen oxides;
Hydrochloric acid gas;
Toxic metals (arsenic, beryllium, cadmium, chromium, nickel, lead, mercury); and
Organics (dioxins/furans, ethylene, propylene).

REGULATORY REQUIREMENTS

EMISSION LIMITS

State regulations are designed to limit air pollutant emissions to certain acceptable levels. The emission limits may be expressed in several different ways depending on the type of pollutant.

The most common type of emission limit is the concentration standard, which limits either the mass (weight) or volume of the pollutant in the gas exiting the stack. This type of emission limit is expressed as follows and is described pictorially in Figure 10-1:

Example	Type of pollutant	Explanation
1 grain per dry standard cubic foot (1 gr/dscf) at 7 percent oxygen	Particulate matter	No more than 1 grain (there are 7,000 grains in 1 pound) of particulate matter may be contained in each cubic foot of gas leaving the stack corrected to 7 percent oxygen and standard conditions (20°C, and 1 atm) (Oxygen correction and standard conditions are explained below)
• 100 parts per million (100 ppm)	Carbon monoxide Sulfur dioxide Nitrogen oxides Hydrogen chloride	No more than 100 cubic feet (cubic meters) of pollutant may be contained in 1 million cubic feet (cubic meters) of gas leaving the stack

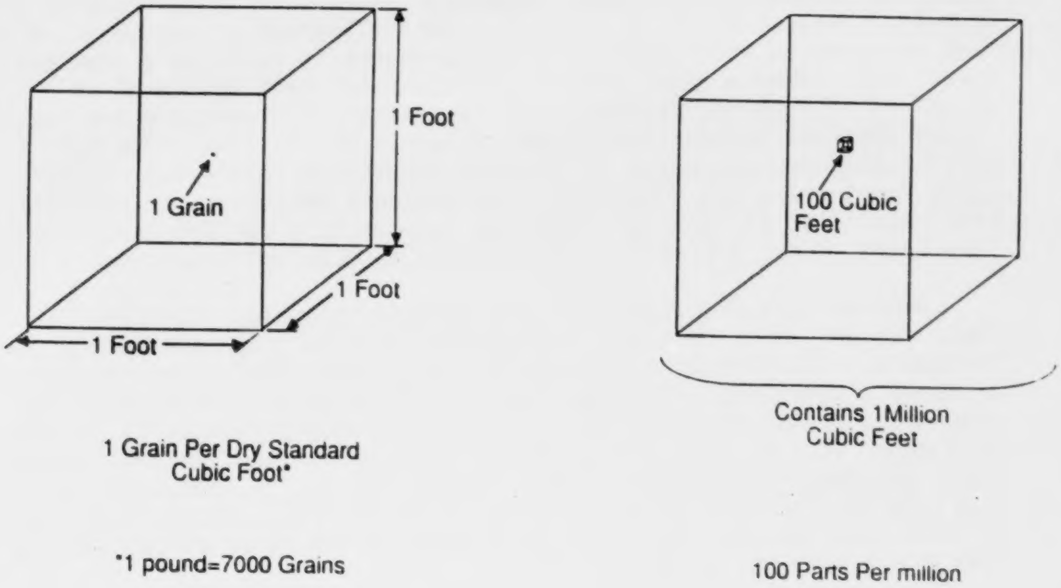
1 Foot
1 Grain
1 Foot
1 Foot
1 Grain Per Dry Standard Cubic Foot*
*1 pound=7000 Grains
100 Cubic Feet
Contains 1Million Cubic Feet
100 Parts Per million

Figure 10-1. Concentration standards.

For metric units, mass/volume concentrations are expressed as milligrams per dry standard cubic meter (mg/dscm). The conversion is:

1 gr/dscf = 2,300 mg/dscm

For metric units, volume/volume concentrations are expressed as ppm. Because a concentration standard limits the amount of pollutant in a certain amount of stack gas, someone having a problem meeting the standard might be tempted to increase the amount of air to dilute the concentration of the pollutant. As air is added, the oxygen concentration in the gas increases because the air contains 21 percent oxygen. To keep this from happening, regulations usually either forbid the addition of dilution air or require that the concentration be "corrected" to a standard level of oxygen, usually 7 percent, or a standard level of carbon dioxide, usually 12 percent. Figure 10-2 illustrates this concept.

Emission limits are often given for standard conditions, e.g. 0.1 grain/dry standard cubic foot. Standard temperature is 68°F (20°C) and standard pressure is 29.92 in. w.c. (760 millimeters of mercury). A cubic foot measured at this temperature and pressure is known as a standard cubic foot. When a stack test is performed to check the level of emissions from an incinerator, both temperature and pressure are measured during the test in addition to the pollutant of interest. The test results are then converted to standard conditions (grain/dry standard cubic foot) using the temperature and pressure measured. In this way, all test results of all sources including incinerators can be compared on the same basis, i.e., all results are reduced to standard conditions.

Another type of standard is the percent reduction standard. Sometimes the emission limit is expressed as a percent reduction of the pollutant. In other words, the pollution control device must operate at or above a specified efficiency level (such as 90 percent removal) to reduce the pollutant emissions. This type standard frequently is used for acid gases such as HCl. For example, if the emission standard requires at least 90 percent reduction of HCl, and the HCl in the combustion gas is entering the scrubber inlet at a rate of 20 lb/h (9.1 kg/h), then the allowed emission rate is 2 lb/h (0.9 kg/h), which is 10 percent of the amount entering the scrubber.

Another type of standard (shown below) sometimes found in State regulations is called an ambient concentration standard. It limits the amount of pollutant that collects at ground level in areas surrounding the emission source. Usually, the regulation requires that the pollutant be measured as it leaves the stack. This measurement information is then used by a computer to calculate the amount of the pollutant at various locations near the source.

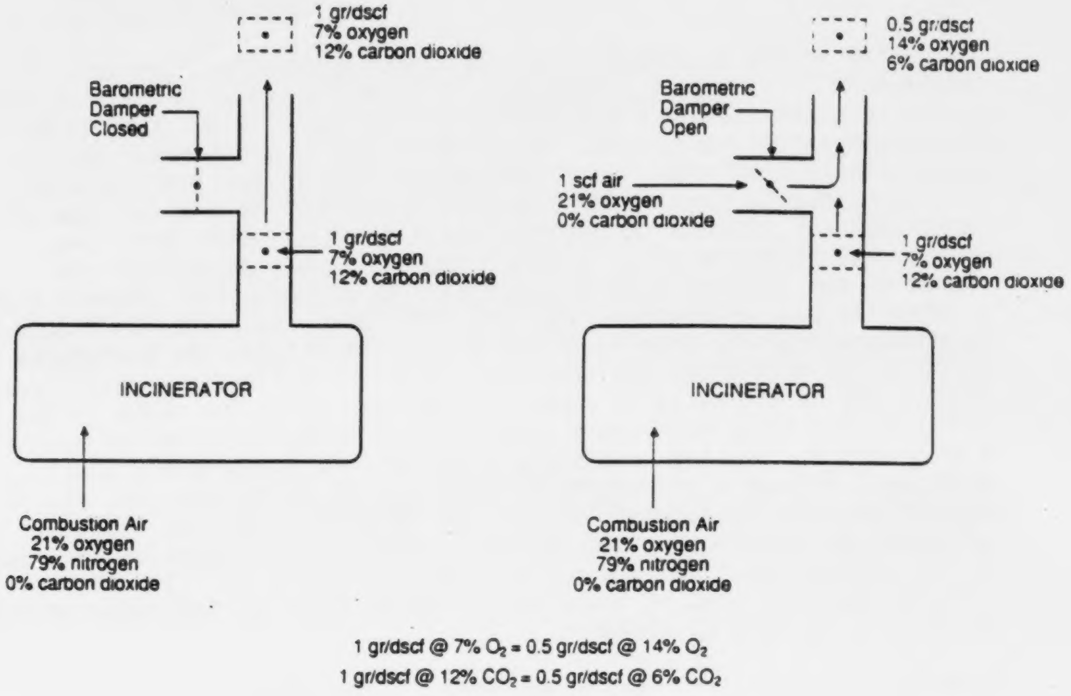
1 gr/dscf
7% oxygen
12% carbon dioxide
Barometric
Damper
Closed
1 gr/dscf
7% oxygen
12% carbon dioxide
INCINERATOR
Combustion Air
21% oxygen
79% nitrogen
0% carbon dioxide
0.5 gr/dscf
14% oxygen
6% carbon dioxide
Barometric
Damper
Open
1 scf air
21% oxygen
0% carbon dioxide
1 gr/dscf
7% oxygen
12% carbon dioxide
INCINERATOR
Combustion Air
21% oxygen
79% nitrogen
0% carbon dioxide
1 gr/dscf @ 7% O_2 = 0.5 gr/dscf @ 14% O_2
1 gr/dscf @ 12% CO_2 = 0.5 gr/dscf @ 6% CO_2

Figure 10-2. Correction for dilution.

Example	Type of pollutant	Explanation
1 microgram per cubic meter (1 $\mu g/m^3$)	Toxic metals Organics Hydrogen chloride	No more than 1 microgram of pollutant may be contained in each cubic meter of air. (There are 1 million micrograms in 1 gram).

A third type of standard that is almost always included in regulations is an opacity standard. It is expressed as a limit on the degree to which the stack emissions are visible and block the visibility of objects in the background. Stack emissions of 100 percent opacity would totally block the view of background objects and indicate high pollutant levels. Zero percent opacity would provide a clear view of the background and indicate no detectable particulate matter emissions. Opacity may be estimated by taking "readings" every 15 seconds and averaging the readings over a specified time period. The "reader" must be a certified opacity reader. The U. S. EPA Reference Method 9 "Visual Determination of the Opacity of Emissions" establishes the procedures and criteria for taking opacity readings and for certification. Additionally, opacity may be estimated by comparing the opacity of the smoke to the six sections of a Ringelmann Smoke Chart. The six sections are numbered from 0 to 5 with No. 0 being completely white and No. 5 completely black. Sections 1 through 4 correspond to opacities of 20 percent (No. 1), 40 percent (No. 2), 60 percent (No. 3), and 80 percent (No. 4). Opacity is estimated by choosing the section which most closely resembles the opacity of the exhaust gas. Opacity may also be measured by an instrument called a transmissometer that is installed in the stack. The following further illustrates an opacity standard.

Example	Type of pollutant	Explanation
10 percent opacity (6-minute average)	Particulate matter	The opacity of the emissions cannot average more than 10 percent for any 6-minute period.

MONITORING AND RECORDKEEPING

- Certain types of records are commonly required by State regulations or operating permits. Most of them are listed below and involve recording the levels indicated on automatic monitoring devices periodically or require recording the parameters continuously.
  - -- Temperature of incinerator chamber(s)
  - -- Oxygen concentration of exhaust gas
  - -- Temperature at inlet and/or outlet of control device
  - -- Continuous emission monitoring records (carbon monoxide or opacity)
  - -- Weight of waste charged to incinerator
  - -- Air pollution control device operating parameters:

a. Scrubber
    - Pressure drop
    - Liquid flow rate

b. Fabric filter
    - Pressure drop

- Keeping good records of instrument readings and operating practices is important because it:
    - -- Helps you to know if a problem develops that would cause air pollution standards to be violated so that you can take corrective action
    - -- Provides proof that you are properly operating and maintaining equipment
    - -- Allows you to prepare accurate annual (or more frequent) reports that may be required by State regulations

ENFORCEMENT OF STATE REGULATIONS

State enforcement officials may inspect your incinerator if complaints are received from neighbors. Frequent complaints may cause officials to make random inspections. A State enforcement official may take the following steps to determine if you are complying with regulations:

- Examine your daily, weekly, and monthly records
- Inspect equipment and monitoring devices
- Observe your work procedures
- "Read" the opacity of stack emissions
- Measure stack emissions ("stack test")

OPERATOR TRAINING

Some State regulations now require that infectious waste incinerator operators be properly trained. The training requirements vary from State to State, but usually include some classroom and hands-on instruction.

YOUR STATE REGULATION

The table on the following pages describes the most common requirements in State regulations for air pollutant emissions from hospital incinerators. There is space in the table for you to list the specific requirements of your State's regulation and how they apply to your incinerator. Your instructor will help you complete this table. Note that the specific limitations in your operating permit are the requirements you must follow.

SUMMARY OF REGULATIONS FOR THE STATE OF ____________

		Your incinerator	
Type of requirement	State regulation	Regulated (Yes/No)	Level
Applicability			
Type of waste charged			
Size of incinerator			
Age of incinerator			
Emission limits			
Particulate matter			
Opacity			
Carbon monoxide			
Sulfur dioxide			
Hydrogen chloride			
Nitrogen oxides			
Toxic metals			
Organics			
Other			
Operating practices			
Limits on chracteristics of waste charged (moisture, volatility, etc.)			
Waste packaging			
Waste charging practices			
Primary chamber temperature			
Secondary chamber temperature			
Residence time			
Feed rate			
Ash burnout levels			
Ash handling and disposal practices			
Shutdown requirements			
Control device temperature			
Other			

(continued)

SUMMARY OF REGULATIONS FOR THE STATE OF ____________
(continued)

Type of requirement	State regulation	Your incinerator	
		Regulated (Yes/No)	Level
Equipment requirements			
Incinerator design			
Interlock systems			
Automatic charging			
Automatic ash removal			
Other			
Recordkeeping			
Incinerator temperature			
Primary chamber			
Secondary chamber			
Control device			
Temperature			
Pressure drop			
Liquid flow rate			
Continuous monitoring records			
Weight of waste charged			
Other			
Continuous emission monitoring			
Opacity			
Sulfur dioxide			
Nitrogen oxides			
Hydrogen chloride			
Carbon monoxide			
Other			
Operator training			

REVIEW EXERCISE

1. State regulations may include which of the following? a. Air pollution emission limits b. Operating limits c. Monitoring and recordkeeping requirements d. Requirement for operator training 1. a 2. b and c 3. d 4. a, b, c, and d	
2. State regulations may be different for different size incinerators. True or False?	1. 4. a, b, c, and d
3. The State or local agency can include special rules and limitations in your permit to operate that are more strict than typical State regulations. True or False?	2. True
4. Which of the following operating practices are sometimes regulated by States? a. Waste packaging and waste charging practices b. Ash handling and disposal practices c. Temperatures and residence times for incinerator chambers d. All of the above e. a and b above	3. True
5. Some State regulations require that incinerator operators be trained. True or False?	4. d. All of the above

(continued)

REVIEW EXERCISE (CONTINUED)

6. Name at least two types of records that you may be required to keep by State regulations.	5. True
7. Which of the following might an enforcement official do to determine if you are complying with regulations? a. Examine your records b. Inspect equipment c. Observe your work procedures d. Sample stack emissions e. All of the above	6. Any of the following: temperature of incinerator chamber(s), control device temperature, emission levels, opacity, weight of waste charged, scrubber pressure drop or liquid flow rate
8. When the stack gases are perfectly clear, that is the same as ______ percent opacity	7. e. All of the above
9. The greater the opacity reading, the better. That is, 30 percent opacity is better than 10 percent opacity. True or False?	8. zero
	9. False

SESSION 11.
SAFETY: AN IMPORTANT PART OF YOUR JOB

SESSION 11. SAFETY: AN IMPORTANT PART OF YOUR JOB

TABLE OF CONTENTS

Page

SESSION GOAL AND OBJECTIVES.................................. 11-1

WASTE HANDLING... 11-1
  "Red Bag" Waste.. 11-1
  Possible Health and Safety Problems with Red Bag Waste..... 11-3
  How to Avoid These Problems................................ 11-3

INCINERATOR OPERATION.. 11-6
  Possible Injuries and Safety Hazards....................... 11-6
  General Safety Precautions................................. 11-6
  Burner Safety Precautions.................................. 11-6
  Charging Safety Precautions................................ 11-6
  Ash Removal Safety Precautions............................. 11-6

AIR POLLUTION CONTROL DEVICE OPERATION....................... 11-8
  Wet Scrubbers--Possible Injuries and Hazards............... 11-8
  Wet Scrubbers--Safety Precautions.......................... 11-8
  Fabric Filters--Possible Hazards........................... 11-9
  Fabric Filters--Safety Precautions......................... 11-9
  Proper Protective Clothing and Safety Equipment............ 11-10

REFERENCES... 11-15

LIST OF FIGURES

Figure 11-1. The biological hazard symbol.................... 11-2
Figure 11-2. Torn waste bag.................................. 11-4
Figure 11-3. Proper safety gear.............................. 11-5

SESSION 11.
SAFETY: AN IMPORTANT PART OF YOUR JOB

SESSION GOAL AND OBJECTIVES

GOAL

To familiarize you with steps you can take to prevent job-related injury and disease.

Objectives

Upon completing this session, you should be able to:

1. Name the activities in your job that could expose you to possible injury or disease if you do not take proper precautions;
2. Name the types of containers used for infectious waste;
3. Describe proper waste-handling procedures;
4. List the protective clothing and safety equipment you should wear on the job;
5. Recognize the types of waste that must be discarded in red bags;
6. Name types of materials that should never be fed into an incinerator;
7. Describe the safety precautions to take when charging the incinerator;
8. Describe the safety precautions to take when removing the ash from the incinerator ash compartment;
9. Describe the safety precautions to take when working around the chamber of a mechanical ram feeder, ash conveyor, or incinerator;
10. Recognize the parts of the incinerator around which special precautions are necessary;
11. Name the hazards associated with wet scrubber and fabric filter operation and how to avoid them.

WASTE HANDLING

"RED BAG" WASTE

Hospital infectious wastes usually are discarded in red plastic bags or containers marked with the universal biological hazard symbol. (See Figure 11-1.)

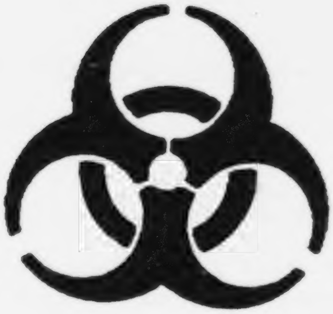

Figure 11-1. The biological hazard symbol.[1]

Listed below are the types of hospital waste that are considered infectious:

- Waste that has been in contact with isolation patients with communicable diseases;
- Microbiological laboratory wastes, including cultures and stocks of infectious agents;
- Blood, blood products, and body fluids;
- Pathological wastes;
- Sharps (needles, laboratory glass wastes, etc.); and
- Human and animal tissue, body parts, and bedding.

POSSIBLE HEALTH AND SAFETY PROBLEMS WITH RED BAG WASTE

- Sharp objects (e.g., needles) might pierce through a bag and pierce your skin.
- Infectious waste might spill onto your skin or clothing if a bag is opened or torn. (See Figure 11-2)
- Airborne micro-organisms might be inhaled.
- Micro-organisms might be swallowed.

HOW TO AVOID THESE PROBLEMS

DO

- Keep bags from tearing or breaking open by:
  - -- Handling bags as little as possible.
  - -- If necessary, asking hospital management to use:
    Stronger or double bags, and/or
    Cardboard containers or rigid carts to hold bags until they are burned.
- Wear proper protective clothing and safety equipment (See Figure 11-3)
  - -- Thick rubber gloves
  - -- Hard-soled rubber shoes
  - -- Safety glasses
  - -- Dust mask
  - -- Disposable coveralls or hospital scrubs
- Change clothing and launder daily
- Wash hands with soap after handling waste and before eating or drinking.

DO NOT

- Open bags.
  - Crush/compact bags.
  - Eat or drink around incinerator.

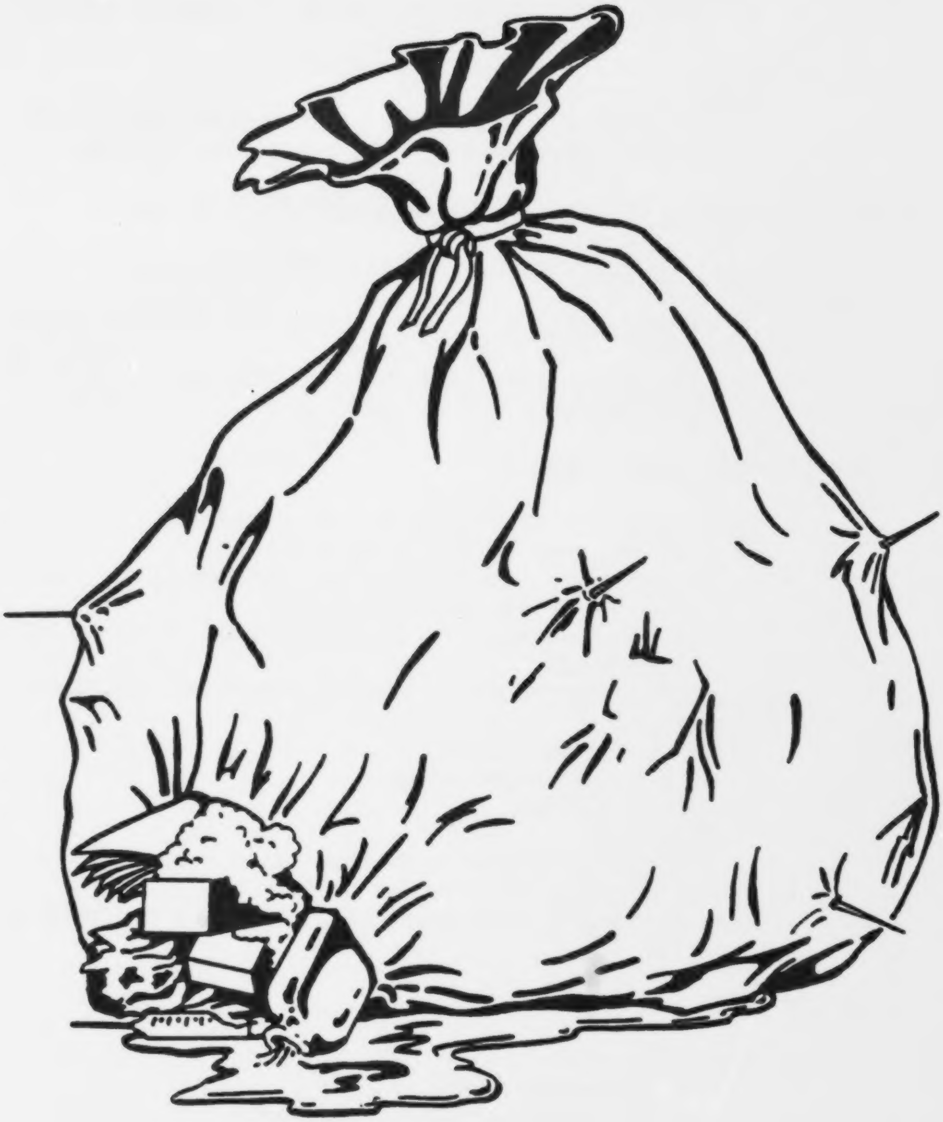

Figure 11-2. Torn waste bag.

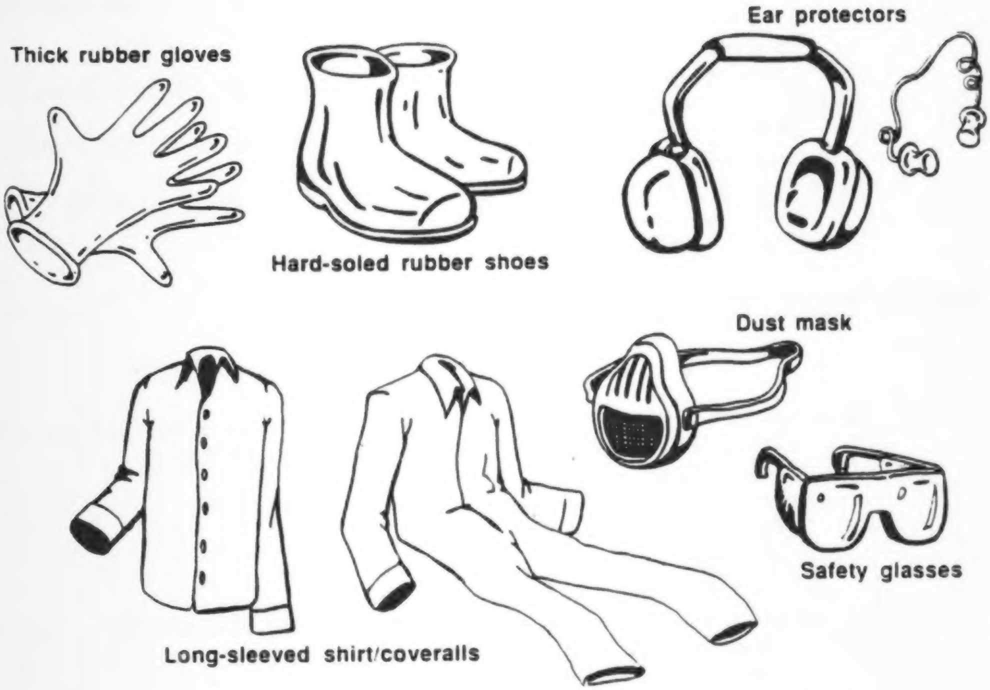
Thick rubber gloves
Hard-soled rubber shoes
Ear protectors
Dust mask
Safety glasses
Long-sleeved shirt/coveralls

Figure 11-3. Proper safety gear.

INCINERATOR OPERATION

You may face a number of potential hazards in operating a hospital incinerator that can be avoided if you take the proper precautions.

POSSIBLE INJURIES AND SAFETY HAZARDS

- Burns caused by:
  - -- Contact with hot surfaces of incinerator or other equipment
  - -- Careless charging procedures
  - -- Careless ash removal procedures
  - -- Opening inspection ports when incinerator is operating
- Injury caused by:
  - -- Getting too close to moving belts or hydraulic cylinders
  - -- Lack of caution on elevated walkways
- Exposure to air contaminants or lack of oxygen caused by:
  - -- Leak in equipment or ductwork
  - -- Poor ventilation of area

GENERAL SAFETY PRECAUTIONS

DO

- Wear proper protective clothing with no loose flaps, belts, etc., that might get caught on moving mechanical parts
  - Thick rubber gloves
  - Hard-soled rubber shoes
  - Safety glasses
  - Dust mask
  - Disposable coveralls
- Be careful around all moving belts, hydraulic cylinders, and doors
- Avoid contact with hot surfaces of:
  - Incinerator chamber
  - Heat recovery equipment (boiler)
  - Ductwork
  - Stack
- Be on the lookout for fuel (gas/oil) leaks.
- Use caution on elevated walkways and keep your hands on the siderails. Be alert to gaps in the walkway or obstacles you could trip over.
- If you notice unusual odors around an indoor incinerator, open doors or windows to ventilate the room.
- If you develop any of the following symptoms that may indicate contaminated air or lack of oxygen, leave the area immediately:
  - Headache
  - Drowsiness
  - Shortness of breath
  - Nausea
  - Loss of coordination
  - Eye irritation

DO NOT

- Open inspection ports to look into the incinerator during operation.

- Place hands or feet into mechanical chambers of feed ram assembly or ash removal system. These units are often automatically operated. (Allow the Maintenance Department to properly deactivate, lockout, and fix if jams occur.)
- Lean on guardrails for elevated walkways or place your hands on equipment surfaces next to the walkway.

BURNER SAFETY PRECAUTIONS

Auxiliary fuel burners are equipped with flame safeguard systems which control the burner ignition process. The safeguard system is a safety feature designed to:

- Prevent the burner from igniting until it has gone through a purge cycle;
- Shut off the fuel supply if the burner fails; and
- Shut off the fuel supply if the combustion air supply fails.

If the system is not properly purged prior to ignition an explosion could occur.

You should never try and override the flame safeguard system; it is there to protect you.

CHARGING SAFETY PRECAUTIONS

DO

- Wait until previous charge has burned down.
- Be sure the primary chamber burner is off.
- Stand behind and away from the door.

DO NOT

- Look into open charge door.
- Charge bottles containing flammable liquids or explosives.

ASH REMOVAL SAFETY PRECAUTIONS

DO

- Use either
  - The mechanical ash ram or conveyor (if available), or
  - Rakes or flat shovels with handles long enough to reach the back of the compartment.
- Be careful of "hot spots" and sharp objects in the ash.
- Place ash into a noncombustible heat-resistant container (metal) and dampen with water to cool it and to reduce fugitive emissions (dust).

DO NOT

- Enter the incinerator chamber.
- Damage the incinerator refractory with the shovel or rake.
- Spray water into chamber.
- Handle ash directly; if you must pick something up by hand, wear protective gloves.

AIR POLLUTION CONTROL DEVICE OPERATION

The two types of air pollution control devices that you are most likely to find at a hospital incinerator are wet scrubbers and fabric filters. This section contains information about hazards associated with control devices and safety precautions that you should know.

WET SCRUBBERS--POSSIBLE INJURIES AND HAZARDS

- Chemical burns can be caused by the scrubber liquor if it gets on your skin or in your eyes.
- Falls could occur on wet areas around the scrubber caused by leaks in the scrubber vessel, ductwork, or piping.
- Injury could result from getting too close to a fan or fan belt drive assembly, in which clothing could get caught. A vibrating fan could cause the fan assembly to disintegrate, causing serious injury.
- Hearing loss could be caused by the noise of operation of the scrubber.

WET SCRUBBERS--SAFETY PRECAUTIONS

DO

- Avoid contact with scrubber liquor. If it does get on your skin or in your eyes, flush with water for at least 15 minutes, and seek medical attention for eye injuries.
- Know the location of the nearest eyewash and how to use it.
- Be alert for scrubber leaks and potential slippery walkways. Ask maintenance to repair major leaks.
- Stay clear of rotating fan drive shafts where clothing could get caught.
- Stay clear of fan belt drive assembly where clothing could get caught or belts could break.
- Protect your hearing by wearing earplugs or earmuffs.

DO NOT

- Place hand in fan belt/pulley assembly.
- Continue to operate scrubber if fan is severely vibrating; shut down incinerator and call maintenance.

FABRIC FILTERS--POSSIBLE HAZARDS

- Exposure to toxic chemicals could occur when handling dust collected from the fabric filter.
- Exposure to excessive heat will occur if you get too close to or touch the surfaces of the fabric filter. Fabric filters generally operate at about 350°F (180°C).
- Injury could result from getting too close to a fan or fan belt drive assembly in which clothing could get caught. A vibrating fan could cause the fan assembly to disintegrate, causing serious injury.
- Hearing loss could be caused by the noise of the operation of the fabric filter.
- Special hazards are inside the fabric filter, where you may be required to go. However, you should enter a fabric filter ONLY IF YOU HAVE BEEN SPECIFICALLY TRAINED AND EQUIPPED to survive the potential hazards inside. These hazards include the following:
  - Toxic gases and dust
  - Hot, free flowing solids
  - Oxygen deficiency
  - High voltage
  - Moving mechanical parts

FABRIC FILTERS--SAFETY PRECAUTIONS

DO

- Wear a dust mask to keep from inhaling dust.
- Protect your hearing by wearing earplugs or earmuffs.
- Stay clear of rotating fan drive shafts where clothing could get caught.
- Stay clear of fan belt drive assembly where clothing could get caught or belts could break.
- If you must enter the fabric filter:
  - Thoroughly clean bags and hopper with mechanical vibration before entering.
  - Purge the incinerator and fabric filter with air to drive out exhaust gases before entering.
  - Be sure fan is "locked out".
  - Be sure a second person is watching you in case you need help. This person should be trained to go for help if needed and should never enter the fabric filter, too.
  - Stay in the fabric filter for as short a time as possible.

DO NOT

- Place hand in fan belt/pulley assembly.
- Continue to operate fabric filter if fan is severely vibrating; shut down incinerator and call Maintenance Department.
- NEVER ENTER FABRIC FILTER UNLESS YOU HAVE BEEN PROPERLY TRAINED AND EQUIPPED.

PROPER PROTECTIVE CLOTHING AND SAFETY EQUIPMENT

To protect yourself from possible injury or exposure to harmful substances, wear the following items when working on a control device:

- Eye protection (safety glasses)
- Hearing protection
- Long-sleeved shirt
- Rubber gloves
- Hard-soled rubber shoes
- Dust mask

REVIEW EXERCISE

1. The reason you need to be especially careful when handling red bag waste is because it might contain one or more of the following things that could be harmful to you.
   a. Human blood and blood products
   b. Pathological wastes
   c. Needles
   d. Explosive chemicals
   e. All of the above
   f. a, b, and c above

2. Hospital infectious waste usually is discarded in red plastic bags or containers marked with which of the following symbols?

   a. The universal biological hazard symbol
   b. A label that says "DANGER-HAZARD"
   c. A picture of a skull and crossbones

3. To help keep waste bags from tearing or breaking open, you should ____________ them as little as possible.

4. If a red bag appears to contain a suspicious substance, you should open it to be sure it is okay to put in the incinerator. True or False?

5. Name the proper clothing and equipment you should wear when handling waste.

1. f. a, b, and c above

2. a.

3. handle

4. False. Never open a red bag.

5. Thick rubber gloves
   Hard-soled rubber shoes
   Safety glasses
   Dust mask
   Disposable coveralls

REVIEW EXERCISE

6. To remove the ash from the back of the ash compartment, you should

   a. Go into the chamber and shovel it out.
   b. Use a rake or flat shovel with a handle long enough to reach the back without you having to enter the chamber.
   c. Flush it out with water.

6. b. Use a rake or shovel with a long handle.

7. If you want to look into the incinerator during operation, it is okay to open an inspection cleanout port. True or False?

7. False

8. When operating the incinerator, you should wear thick rubber shoes, safety glasses, and a dust mask. True or False?

8. True

9. Which of the following symptoms may indicate exposure to air contaminants or lack of oxygen?

   a. Headache
   b. Drowsiness
   c. Shortness of breath
   d. Nausea
   e. Loss of coordination
   f. Eye irritation
   g. All of the above
   h. All except b.

9. g. All of the above

REVIEW EXERCISE

10. You should avoid contact with the scrubber liquor because it

    a. Can cause chemical burns to your skin or eyes
    b. Will make you pass out if you smell it
    c. Will give you a fatal skin disease

10. a. Can cause chemical burns to your skin or eyes

Choose from the following words to fill in the blanks below describing the control device safety hazards you should be aware of: noise, toxic chemicals, fans, leaks, fan belt.

11. Vibrating ____

11. fans

12. __________ in scrubber vessel, ductwork, or piping

12. leaks

13. High __________ levels

13. noise

14. __________ ________ in the dust from the fabric filters

14. Toxic chemicals

15. _______ ________ and pully assemblies

15. Fan belt

16. No special training is required before entering a fabric filter. True or False?

(continued)

REVIEW EXERCISE (CONTINUED)

17. Which of the following hazards are associated with the inside of a fabric filter. a. Toxic gases and dust b. Hot, free flowing solids c. Oxygen deficiency d. High voltage e. Rotating equipment f. All of the above g. All except d	16. False
	17. f. All of the above

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GLOSSARY

GLOSSARY

ABSORPTION.[3] The process by which gas molecules are transferred to (dissolved in) a liquid phase.

ACID GASES.[4] Corrosive gases formed during combustion of chlorinated or halogenated compounds, e.g., hydrogen chloride (HCl).

ACTUAL CUBIC FEET PER MINUTE (acfm).[3] A gas flow rate expressed with respect to temperature and pressure conditions.

AIR, DRY.[4] Air containing no water vapor.

ASH.[5] The noncombustible inorganic residue remaining after the ignition of combustible substances.

ASH COMBUSTIBLES. The fraction of combustible organic material remaining in the bottom ash as measured by the loss on combustion technique.

ATOMIZATION.[4] The reduction of liquid to a fine spray.

AUXILIARY FUEL BURNER. Burner in either the primary or secondary chamber fueled by natural gas or fuel oil. Used to maintain temperature if waste has too little heating value.

BAG BLINDING. The loading, or accumulation, of filter cake to the point where capacity rate is diminished.

BAROMETRIC SEAL.[1] A column of liquid used to hydraulically seal a scrubber, or any component thereof, from the atmosphere or any other part of the system.

BOTTOM ASH.[5] The solid material that remains on a hearth or falls through the grate after incineration is completed.

BURN RATE. The total quantity of waste that is burned per unit of time that is usually expressed in pounds of waste per hour.

BURNDOWN PERIOD. The period of time in an incinerator's operating cycle during which no additional waste is charged to the incinerator and the primary combustion chamber temperature is maintained above a minimum temperature (using auxiliary burners as necessary) to facilitate the solid phase combustion of the waste bed.

BURNOUT. A measure of ash quality; it is the percentage of the ash that is inorganic material.

CHARGE RATE. Quantity of waste material loaded into an incinerator over a unit of time but which is not necessarily burned. Usually expressed in pounds of waste per hour.

CHARGING DOOR. The opening through which waste is charged to the incinerator.

CLEANOUT DOOR. Openings in the primary and secondary chamber that are used to remove ash.

CLINKERS.[5] Hard, sintered, or fused pieces of residue formed in an incinerator by the agglomeration of ash, metals, glass, and ceramics.

COCURRENT OR CONCURRENT.[4] Flow of scrubbing liquid in the same direction as the gas stream.

COLLECTION EFFICIENCY.[1] The ratio of the weight of pollutant collected to the total weight of pollutant entering the collector.

COMBUSTION. A thermal process in which organic compounds are broken down into carbon dioxide (CO_2) and water (H_2O).

COMBUSTION AIR.[5] The air used to burn a fuel or waste.

COMBUSTION GAS.[5] The mixture of gases and vapors produced by burning.

CONDENSATION.[1] The physical process of converting a substance from the gaseous phase to the liquid phase via the removal of heat and/or the application of pressure.

CONTROLLED AIR INCINERATION.[5] Incineration utilizing two or more combustion chambers in which the amounts and distribution of air to each chamber are controlled. Partial combustion takes place in the first zone (chamber) and subsequent zones are used to complete combustion of the volatilization gases.

COOLDOWN PERIOD. The period of time at the end of an incinerator's operating cycle during which the incinerator is allowed to cool down. The cooldown period follows the burndown period.

CROSSFLOW.[4] Flow of scrubbing liquid normal (perpendicular) to the gas stream.

CYCLONE.[4] A device in which the velocity of an inlet gas stream is transformed into a confined vortex from which inertial forces tend to drive particles to the wall.

DAMPER.[2] An adjustable plate installed in a duct to regulate gas flow.

DEMISTER.[4] A mechanical device used to remove entrained water droplets from a scrubbed gas stream.

DENSITY.[2] The ratio of the mass of an object to the volume of the object.

DRAFT.[1] A gas flow resulting from pressure difference; for example, the pressure difference between an incinerator and the atmosphere, which moves the products of combustion from the incinerator to the atmosphere. (1) Natural draft: the negative pressure created by the difference in density between the hot flue gases and the atmosphere. (2) Induced draft: the negative pressure created by the vacuum action of a fan or blower between the incinerator and the stack. (3) Forced draft: the positive pressure created by the fan or blower, which supplies the primary or secondary air.

EXCESS AIR. Burning with combustion air supply greater than stoichiometric air requirements.

FIXED CARBON. The nonvolatile organic portion of waste.

FLAME PORT. Opening between the primary chamber and mixing chamber of a multiple chamber incinerator through which combustion gases pass.

FORCED DRAFT. (See Draft).

FUGITIVE EMISSIONS. Emissions not released through a duct or stack such as furnace leaks and wind blown ash.

GRID.[1] A stationary support or retainer for a bed of packing in a packed bed scrubber.

HEADER.[1] A pipe used to supply and distribute liquid to downstream outlets.

HEATING VALUE. The amount of heat that is released when a material is combusted usually expressed as Btu/lb.

HEARTH.[5] The bottom of a furnace on which waste materials are exposed to the flame.

HEAT INPUT. Total energy released from burning; (heating value [Btu/lb]xfeed rate [lb/h]).

HUMIDITY, ABSOLUTE.[2] The weight of water vapor carried by a unit weight of dry air or gas.

HUMIDITY, RELATIVE.[2] The ratio of the absolute humidity in a gas to the absolute humidity of a saturated gas at the same temperature.

INCINERATOR. A thermal device which combusts organic compounds using heat and oxygen.

INDUCED DRAFT FAN.[3] A fan used to move a gas stream by creating a negative pressure. (See Draft).

INFECTIOUS WASTE. Waste capable of producing an infectious disease in humans.

INORGANIC MATERIAL.[5] Chemical substances of mineral origin, not containing carbon to carbon bond.

INTERLOCK. Part of an automatic control system which tie together operation of different incinerator components.

LIQUID-TO-GAS RATIO.[3] The ratio of the liquid (in gallons per minute) to the inlet gas flow rate (in acfm).

LIQUOR.[1] A solution of dissolved substance in a liquid (as opposed to a slurry, in which the materials are insoluble).

MAKEUP WATER.[3] Water added to compensate for water losses resulting from evaporation and water disposal.

MIST ELIMINATOR.[3] Equipment that removes entrained water droplets downstream from a scrubber.

MIXING CHAMBER. Zone in an excess air incinerator between the primary and secondary chamber where combustion gases and secondary combustion air are mixed.

NATURAL DRAFT. (See Draft).

OPACITY.[4] Measure of the fraction of light attenuated by suspended particulate.

OVERFIRE AIR PORT.[5] Point of entry of combustion air introduced above and beyond the fuel or waste bed.

PACKED-BED SCRUBBER.[3] Equipment using small plastic or ceramic pieces, with high surface area to volume ratios for intimate gas/liquid contact for mass transfer.

PARTICLE.[4] Small discrete mass of solid or liquid matter.

PARTICLE SIZE.[4] An expression for the size of liquid or solid particle usually expressed in microns.

PARTICULATE EMISSION.[4] Fine solid matter suspended in combustion gases carried to the atmosphere. The emission rate is usually expressed as a concentration such as grains per dry standard cubic feet (gr/dscf) corrected to a common base, usually 12 percent CO_2.

PARTICULATE MATTER.[4] As related to control technology, any material except uncombined water that exists as a solid or liquid in the atmosphere or in a gas stream as measured by a standard (reference) method at specified conditions. The standard method of measurement and the specified conditions should be implied in or included with the particulate matter definition.

PATHOGENIC. Waste material capable of causing disease.

PATHOLOGICAL WASTE. Waste material consisting of anatomical parts.

PATHOGEN. Organism capable of causing disease, generally a bacteria or virus.

PENETRATION.[4] Fraction of suspended particulate that passes through a collection device.

pH.[1] A measure of acidity-alkalinity of a solution.

PILOT. A burner that is used to ignite waste and auxiliary fuel during startup.

PLUME. Combustion gases exhausted from the stack.

PRESSURE DROP.[3] The difference in static pressure between two points due to energy losses in a gas stream.

PRESSURE, STATIC.[4] The pressure exerted in all directions by a fluid; measured in a direction normal (perpendicular) to the direction of flow.

PRIMARY CHAMBER. Chamber with hearth or grate that receives waste material and in which the waste is ignited.

PRODUCTS OF INCOMPLETE COMBUSTION. Materials other than carbon dioxide, water, and acid gases that are produced when organic materials are burned.

PYROLYSIS. The chemical destruction of organic materials in the presence of heat and the absence of oxygen.

QUENCH.[1] Cooling of hot gases by rapid evaporation of water.

REAGENT. Reactive material used to remove acid gases from the combustion gases.

RED BAG WASTE. As used in this document, red bag waste refers to infectious waste; the name comes from the use of red plastic bags to contain the waste and to clearly identify that the waste should be handled as infectious.

REFRACTORY.[6] Nonmetallic substances used to line furnaces because they can endure high temperatures and resist abrasion, spalling, and slagging.

RESIDENCE TIME. Amount of time the combustion gases are exposed to mixing, temperature, and excess air for final combustion.

RETENTION TIME. Length of time that solid materials remain in the primary chamber.

SATURATED GAS.[1] A mixture of gas and vapor to which no additional vapor can be added, at specified conditions.

SECONDARY COMBUSTION CHAMBER. Component of the incinerator that receives combustion gases from the primary chamber and completes the combustion process.

SIZE DISTRIBUTION.[4] Distribution of particles of different sizes within a matrix of aerosols; numbers of particles of specified sizes or size ranges, usually in micrometers.

SLURRY.[1] A mixture of liquid and finely divided insoluble solid materials.

SMOKE.[4] Small gasborne particles resulting from incomplete combustion; particles consist predominantly of carbon and other combustible material; present in sufficient quantity to be observable independently of other solids.

SPECIFIC GRAVITY.[1] The ratio between the density of a substance at a given temperature and the density of water at 4°C.

SPRAY NOZZLE.[1] A device used for the controlled introduction of scrubbing liquid at predetermined rates, distribution patterns, pressures, and droplet sizes.

STACK.[5] Any chimney, flue, vent, or duct arranged to discharge combustion gases to the air.

STANDARD CUBIC FEET PER MINUTE (scfm).[3] A gas flow rate expressed with respect to standard temperature and pressure conditions.

STARVED-AIR INCINERATION. Controlled air incineration in which the primary chamber is maintained at less than stoichiometric air conditions.

STOICHIOMETRIC AIR. The theoretical amount of air required for complete combustion of waste to CO_2 and H_2O vapor.

STUFF AND BURN. A situation in which the charging rate is greater than burning rate of the incinerator.

THERMOCOUPLE. A thermoelectric device used to measure temperatures.

TRANSMISSOMETER. A monitoring device used to measure combustion gas opacity.

UNDER-FIRE AIR. Combustion air which enters the fuel bed from orifices in the hearth.

VAPOR.[4] The gaseous form of substances that are normally in the solid or liquid state and whose states can be changed either by increasing the pressure or by decreasing the temperature.

VIEW PORT. Sealed glass ports for observing the combustion chamber during operation.

VOLATILE MATTER. That portion of waste material which can be liberated with the application of heat only.

WET BULB/DRY BULB. Wet bulb temperature is indicated by a wet bulb psychrometer and dry bulb temperature is measured by an accurate thermometer. Together, they provide a measure of relative humidity.

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